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Purification of Waters Discharged from Polish Lignite Mines

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The exploitation of lignite deposits is linked with the necessity of lowering the groundwater table and dewatering the mine of precipitation. A large percentage of the discharge waters requires purification prior to delivery of receiving streams. The chief pollutants of these waters are the oxygen demand, and occasionally high iron. Purification of these waters is limited, as a rule, to a reduction in suspended matter and turbidity. The method most commonly used is sedimentation in large sedimentation basins. For some difficult to purify mine waters and during periods of adverse atmospheric conditions, this technology does not produce satisfactory results. To improve sedimentation basin efficiency studies were conducted utilizing flocculants. The dependence of purification on the length of fast mixing, flocculant dose rates, and concentration of solutions employed were evaluated. The laboratory results were verified in a pilot scale sedimentation basin. The scope of the research included studies of the hydraulics of the sedimentation basin and investigations of flocculant application. The relationships between the dose of flocculant and time of retention and the reduction of suspended solids, turbidity, oxygen demand and other chemical parameters were made. Results of pilot tests confirmed the usability of cationic polyelectrolites in purification of mine waters.

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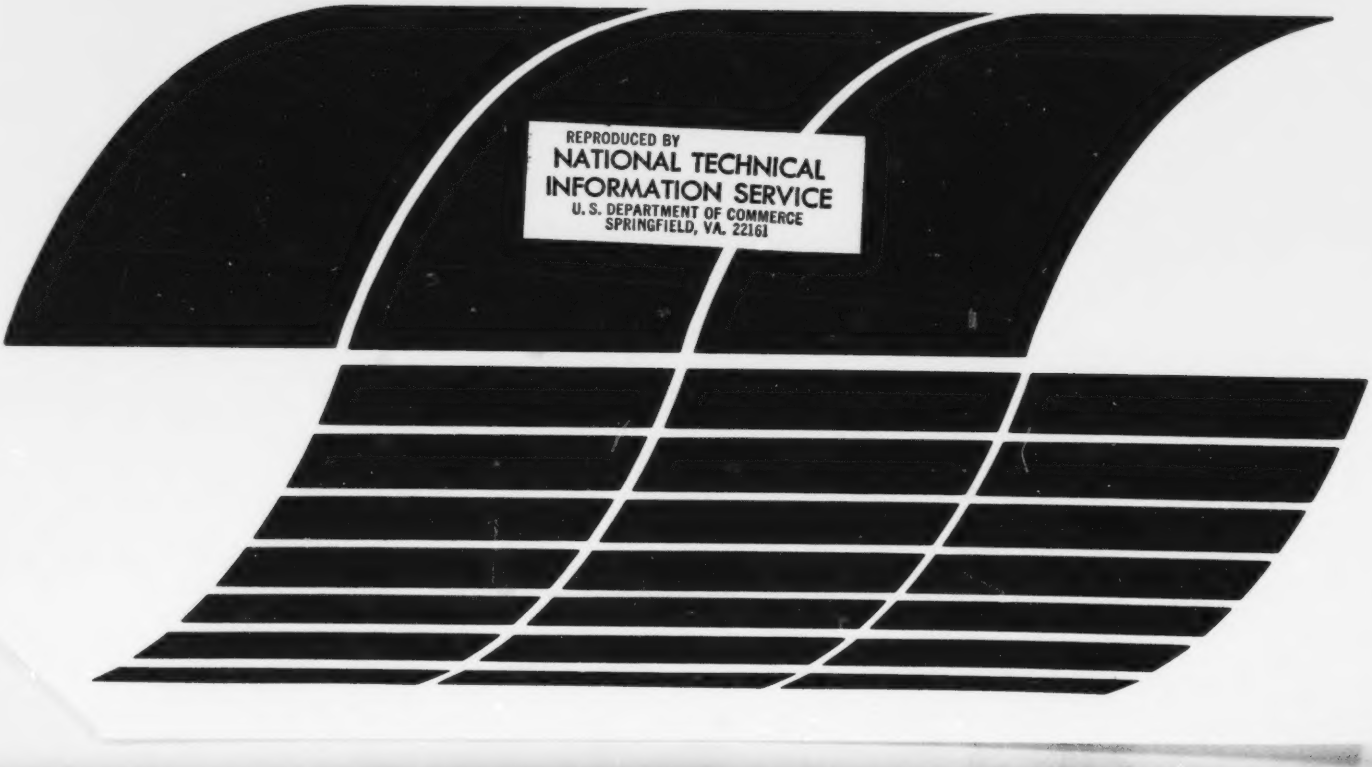

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April 1979

PURIFICATION OF WATERS DISCHARGED FROM POLISH LIGNITE MINES

by

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Contract 05-534-3

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FOREWORD

When energy resources are extracted, processed, converted and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The U. S. Environmental Protection Agency through its Regional Offices and Office of Research and Development is striving to develop and demonstrate new and improved methodologies that will meet these needs both efficiently and economically.

The effort reported here was conducted as part of the Environmental Protection Agency's Scientific Activities Overseas Program. The research was conducted by Poltegor, the Central Research and Design Institute for Openpit Mining, Wroclaw, Poland.

Reported here is a study to improve the performance of sedimentation basins utilized for the treatment of lignite mine discharges. Emphasis was placed on the use of flocculants as an aid to purification. Results of this work will be of interest to persons designing sedimentation basins. Furthermore, it should be of interest to those persons developing regulations and reviewing mine treatment schemes.

For further information contact the Resource Extraction and Handling Division, IERL-Cincinnati.

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SCIENTIFIC ACTIVITIES OVERSEAS

(Special Foreign Currency Program)

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Scientific Activities Overseas not only supplement and complement the domestic mission of EPA, but also serve to carry out the mandate of Section 102(2(E)) of the National Environmental Policy Act to "recognize the worldwide and long-range character of environmental problems, and where consistent with the foreign policy of the United States, lend appropriate support to initiatives, resolutions, and programs designed to maximize international cooperation in anticipating and preventing a decline in the quality of mankind's world environment".

This study of purification of waters from open-pit lignite mines has been funded from Public Law 480. Excess foreign currency money is available to the United States in local currency in a number of countries, including Poland, as a result of a trade for U. S. commodities. Poland has been known for its extensive mining interests, environmental concern, and its trained and experienced engineers and scientists in this important energy area.

ABSTRACT

The exploitation of lignite deposits is linked with the necessity of lowering the groundwater table and dewatering the mine of precipitation. A large percentage of the discharge waters requires purification prior to delivery to receiving streams. The chief pollutants of these waters are the high content of mineral and organic suspended matter, turbidity, color, oxygen demand, and occasionally high iron. Purification of these waters is limited, as a rule, to a reduction in suspended matter and turbidity. The method most commonly used is sedimentation in large sedimentation basins. For some difficult to purify mine waters and during periods of adverse atmospheric conditions, this technology does not produce satisfactory results.

To improve sedimentation basin efficiency studies were conducted utilizing flocculants. Eighteen American and Polish flocculants were tested on a laboratory scale. The best results were obtained employing cationic polyelectrolites of the Calgon M-502 type of American production and Rokrysol WF-5 of Polish production. These polyelectrolites caused agglomeration of the suspensions and formed floccules that had good settling characteristics. The dependence of purification on the length of fast mixing, flocculant dose rates, and concentration of solutions employed were evaluated.

The laboratory results were verified in a pilot scale sedimentation basin. The scope of the research included studies of the hydraulics of the sedimentation basin and investigations of flocculant application. The relationships between the dose of flocculant and time of retention and the reduction of suspended solids, turbidity, oxygen demand and other chemical parameters were made.

Results of pilot tests confirmed the usability of cationic polyelectrolites in purification of mine waters. Optimal doses for Calgon M-502 were from 0.75-1.5 ppm, and for Rokrysol WF-5, 10-20 ppm. Optimum retention times in the sedimentation basin with the additions of flocculant was within the range of 3-8 hours, which resulted in a reduction in turbidity of 70-80%.

This report was submitted in fulfillment of Contract No. 05-534-3 by the Central Research and Design Institute for Openpit Mining, Poltegor, Poland, under the sponsorship of the U. S. Environmental Protection Agency. This report covers a period from September 1, 1974 to August 1, 1977.

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- -Institute of the Environment Protection Engineering of the Wroclaw Technical University
- -Zjednoczone Zaklady Urzadzen Jadrowych POLON in Poznan
- -Geological Institute in Wroclaw
- -Zaklady Badawcze Nadodrzanskich Zakladow Przemyslu Nieorganicznego ROKITA in Brzeg - Dolny near Wroclaw
- -Open-pit lignite mine "Adamow" in Turek.

The research was conducted and the report prepared by Mr. Henryk Janiak, M.Sc., Principal Investigator. For the U. S. Environmental Protection Agency, Ronald Hill, Director, Resource Extraction and Handling Division, Industrial Environmental Research Laboratory-Cincinnati, Cincinnati, Ohio, served as Project Officer.

We herewith express the acknowledgments and gratitude to the Project Officer for his assistance and advice for supplies, materials and publications, and flocculants of American production necessary to perform the field and laboratory tests, and for making possible contacts with appropriate institutions in the U.S.A., that allowed us to get acquainted with American experiments within the scope of this project.

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SECTION 1

SUMMARY

The object of this research work was the improvement in the technology of removing suspended matter from waters drained from lignite mines. As much as 70 m^3/min of polluted water is pumped from the Polish lignite open-pit mines. Very often the only pollutants of these waters are the high concentrations of suspended matter (up to 7,500 ppm), turbidity (up to 1,000 NTU) and oxygen demand (up to 600 ppm). The remaining physico-chemical parameters usually are within the limits permitted for waters to be discharged to ground or surface receivers.

The main source of the pollution are the mineral and coal suspended particles washed with underground or rain waters from the slopes and benches of the open-pit workings. The suspended particle loads are a function of the quantity of run off waters, the geological-hydrological and exploitation factors, and the meteorological and climatic conditions.

High turbidity and suspended matter concentrations occur particularly during or immediately after the occurrence of atmospheric precipitations or spring thaws creating dangers of pollution to surface receivers such as streams, lakes and water reservoirs. The presence of suspended matter deteriorates the conditions for biological life development in the receivers and diminishes the quantities of available pure water in areas often deficient in water.

Up to the present time the purification of mine waters for suspended solids has taken place in large sedimentation basins utilizing gravitational sedimentation. This practice required the construction of large sedimentation basins (as large as 20 hectares) in order to provide more than 1 day of retention time and to obtain the required reduction in suspended matter. Large sedimentation basins, apart from the fact they occupy large areas, are costly and difficult to construct and are vulnerable to atmospheric conditions. With the occurrence of high wind velocities, the effect of water purification in these sedimentation basins is unsatisfactory. Moreover, in some mines the waters contain large quantities of fine grained colloidal suspensions with high potentials and stabilized colloidal elements that are difficult to remove by gravitational sedimentation.

The necessity to improve the effectiveness of mine waters purification evolved from the imperfection of the employed technology and from a gradual tightening of regulations concerning the quality of waters which could be discharged to surface receivers. Investigations were carried out in the following areas:

- Improving the effectiveness of sedimentation basins through the adoption of appropriate shape and size of the basin to obtain optimum hydraulic conditions
- Improving the processes of mining and drainage in order to limit the proportion of polluted waters to the total quantity of mine drainage
- Development of new methods of purification such as coagulation, flocculation, radiation and filtration to improve suspended solids removal.

The research report here concentrated on the application of the flocculation processes for water purification. Laboratory investigations of the usability of a radiation process for the mine water purification are summarized in a separate report.

The research was comprised of the following:

- survey and literature review of research in the field of purification of waters drained from lignite mines
- characterization of mine waters in the light of Polish regulations, and of methods used for purification of mine waters.
- laboratory investigations of 18 synthetic flocculants to assist in the purification of mine waters
- laboratory investigations to determine those factors that influence the use of flocculants to treat mine waters
- construction of an experimental sedimentation basin to enable performance testing of flocculants on a pilot scale
- hydraulic investigations of the experimental sedimentation basin in order to establish design criteria for sedimentation basins
- tests with the optimum flocculants as found in the laboratory studies, to verify the results on a pilot plant scale

The overall object of the research work was the development of technology to purify mine water so that the suspended matter would be under 30 ppm, utilizing for this purpose synthetic flocculants.

The results of this research, other research by Poltegor and research by others has provided the following conclusions. Dependent on the quality of waters drained from the lignite mines and on the required reduction in suspended solids one can employ one of three technologies for purification.

1. In waters with low or average suspended matter (the mines from the regions of Konin and Adamow), and a required treatment to 30 ppm can be obtained by the use of sedimentation basins alone.

2. In case of waters in item 1, where the required treatment to below 30 ppm of suspended solids for the whole year, the employment of sedimentation aided with synthetic flocculants is recommended.

3. In the case of mine waters that are difficult to purify, such as at the mine Turow, coagulation aided with flocculants should be used. In cases

where the water is to be utilized for drinking or for industrial processes the use of filtration through appropriate sandbeds is recommended.

Discussed in detail in this report is the technology of purification with use of flocculants. The results of these investigations prove the usability of cationic flocculants in the reduction of suspended solids and turbidity in water drained from Polish lignite mines. Best results were obtained with Calgon M-502, which in small doses obtained a high level of turbidity removal and were able to reduce suspended solids to below 30 ppm and even to under 20 ppm. In the course of the research work there were established a number of qualitative and quantitative relationships which afford design information for treatment facilities. However, it should not be concluded that these investigations have exhausted all the possibilities of improving the effectiveness of the mine waters' purification.

The utilization of these results for American mine conditions characterized with different geological-hydrological and mining features, with different meteorological and other conditions would require verifying tests. The results of these tests should help to specify a program for such tests, the methodology for their performance, a timetable and the expected effects.

SECTION 2

CONCLUSIONS

The results of these investigations on the removal of suspended matter from waters drained from lignite mines having an average turbidity of 100 NTU, mineral-organic suspended matter of 300 ppm (periodically up to 1000 ppm), pH between 6.5 and 8.5, temperature up to 23°C, iron content to 3 ppm Fe and a colloidal particles potential under -30 uV are described below. The goal of the purification was to reduce the suspended matter to below 30 ppm.

CONCLUSIONS DRAWN FROM LABORATORY INVESTIGATIONS

1. The investigations have shown, that for mine waters with an average concentration of suspended matter up to 300 ppm (mines of Konin and Adamow), good effects were obtained using cationic flocculants. The best were Calgon M-502 and M-503 of the U.S.A. production, and Rokrysol WF-5 of Polish production. Optimum doses of Calgon was to 0.1-3.0 ppm, and of Rokrysol 10-20 ppm. Reduction of turbidity was up to 99%, and the oxygen demand up to 70%.

2. In the case of waters more difficult to purify and containing large quantities of fine grained suspensions with a low potential (under -30 uV), purification with the use of flocculants did not always give satisfactory results. For these waters conventional coagulants, such as lime, were better.

3. The investigations did not indicate any influence of water temperature on the effect of purification within the temperature range of 0 - 23°C.

4. The investigations did not indicate any influence of pH on the effects of purification within the range 6.5 to 8.5. However, pH's over 9.0 induced improvement in the suspended matter reduction when flocculants were used.

5. The investigations proved an influence of the length of time of fast mixing when cationic flocculants were used. The best results were achieved when employing fast mixing for 8 to 10 minutes. Further increases in the time of fast mixing to 30 minutes improved the performance only slightly. Positive results were achieved with compressed air induced fast mixing for 10 minutes, and then with mechanical mixing for about 3 minutes.

6. On the basis of the laboratory tests Calgon M-502, and Rokrysol WF-5 were selected as the best for pilot plant testing.

CONCLUSIONS DRAWN FROM HYDRAULIC TESTS OF THE EXPERIMENTAL SEDIMENTATION BASIN

1. Hydraulic tests were carried out utilizing tracers isotopes and fluorescein dyes. The results showed that both tracers are suitable for this type of test and the results are similar. When fluorescein is used, care should be taken to remove completely the suspended matter from the samples. This can be achieved by employing filtration, centrifugation, or sedimentation for a specified time. Fluorescein is sensitive to strong sunlight and within a few hours will gradually fade out of the solution.

2. The curves of flow acquired in this study are characterized of the typical shape of those from elongated sedimentation basins and have clearly marked maxima of tracer concentrations and the rising and falling curve arms approach the established background values.

3. The analysis of the flow wave curves were carried by a number of methods, of which the Wolfe-Resnick method gives the greatest values for the active volume of the sedimentation basin. The real active volume of the sedimentation basin by this method was 58-89% and the dead spaces was 11-42%. At a basin depth of 1.20 m the active area was higher (72-89%), than when the depth was 2.20 m (58-81%).

4. The proportion of flow of the piston type amounted to 13 to 53% and of perfect mixture flow from 47 to 87%. On the basis of results of these tests, an increase in theoretical retention time decreased the proportion of piston flow.

5. Normal active volume in the sedimentation basin was 49-75%, and standard active volume was from 33-65%. These values were much lower from the real active volume of the sedimentation basin (58-89%).

6. For the same inflow, the coefficient of utilization and real active volume was greater for a 1.2 m depth than a 2.2 m depth, although the theoretical detention time was greater for the greater depth.

7. Average velocities of water flow in the tested sedimentation basin fluctuated from 0.11 m/min to 0.88 m/min. No clear relationship could be established between the velocity of flow and the active volume.

8. The Freude's number for the tested flows were within the limits of 10^{-6}-10^{-7}, and only in one case came to 10^{-5}. No clear relationship was found between the Freude's number and the remaining parameters of flow.

9. The Reynold's number for the tested flows fluctuated from 1160 to 9835. On the basis of these results an increase in Reynold's caused a decrease in active volume and increased the piston flow within the sedimentation basin.

CONCLUSIONS DRAWN FROM FIELD TESTS OF CALGON M-502 AND ROKRYSOL WF-5

1. The physical-chemical composition of the mine waters during the period of tests was subject to significant fluctuations, especially in turbidity,

suspended matter and oxygen demand. The quality of the mine waters was dependent on the hydrogeological conditions, the extraction of the lignite deposit, the draining of the mine working, and on atmospheric conditions.

2. During the period of research performance two types of water could be distinguished, i.e., waters with coarsely grained suspensions not having high turbidities (occurred in 1976) and waters with large amounts of fine granulated suspension characterized by high turbidity in relationship to the suspended matter (occurred in 1977). The waters differed in their turbidity values but had small differences in average suspended matter.

3. The characteristics of the suspensions in the mine waters caused differences in the effects of water purification with or without the use of flocculants.

4. The investigations showed that reduction in the mine water turbidity by sedimentation alone was proportional to the time of retention in the sedimentation basin. For retention times of 1 to 15 hours, the average turbidity reduction amounted to 0-51%, respectively.

5. Aiding the sedimentation process by an addition of Calgon in a quantity of 0.5 ppm increased the suspended solids reduction or could reduce the required volume of the sedimentation basin by a third and still provide a turbidity reduction of 51%. Increasing in the dose of flocculant to 1 ppm improved turbidity reduction to 70-75% and a dose of 1.5 ppm to about 77% (with retention of 15 hours). Further increase in the dose to 4 ppm did not increase materially the reduction in turbidity.

6. Addition of a flocculant effectively reduced the turbidity and suspended solids, especially with short times of retention up to 5 hours.

7. The investigations showed the optimum dose of Calgon M-502 was between 1.0 and 1.5 ppm. Dependent on the quality of the mine water the time, and method of rapid mixing, this dose could be increased or decreased within the limits of 0.75 - 2.0 ppm.

8. The capacity of the sedimentation chamber should ensure a real time of retention of water of 3-8 hours. Further increase in the time of retention with the application of an optimum dose of flocculant improved the effects of purification only slightly. This retention time corresponds to an average real velocity of flow through the sedimentation chamber of 2-6 mm/sec.

9. The tests did not indicate an influence of temperature (within limits of 6-23°C) on the purification process.

10. The experimental sedimentation basin was not influenced by atmospheric conditions, especially wind. No influence in basin depth (1.20 - 2.20 m) on purification was observed.

11. Extension of the time of fast mixing to more than 10 minutes with the application of a compressed air stream in a special chamber improved the reduction in turbidity (12%) and oxygen demand (30%) without increasing the doses of flocculants.

12. Comparing the effects of purification of waters in the field sedimentation basin "Teleszyna" (no flocculation and long retention times up to 5 days) with the experimental sedimentation basin (no flocculation and maximum retention 15 hours), it was found that the similar results were achieved. Turbidity of water flowing from the sedimentation basin "Teleszyna" during times when the wind velocity was not exceeding 3-4 m/sec in 1976 was 18-19 NTU, however, in 1977 it was 25-31 NTU.

13. Water sampled at 1/2 and 3/4 of the distance from the inlet indicated that the basic process of suspended solids reduction was taking place in the area between the inlet and 1/2 the distance for both the full scale and experiment basin. Reduction in turbidity within this area in a majority of the tests constituted 70-80% of the total reduction.

14. Rokrysol WF-5 was an effective flocculant in doses of 10-20 ppm. Reduction in turbidity with the application of this flocculant and a retention time of 5 hours was close to 60%, producing a concentration of suspended matter in the purified water under 30 ppm in case of mine waters with average pollution. With waters with high concentration of suspensions, removal was under 50 ppm. Reduction in oxygen demand was to 70-80%.

15. Application of Rokrysol with prolonged fast mixing of the flocculant in an aeration chamber improved the effects of water purification. Reduction in turbidity was increased by 10-15%, and in oxygen demand up to 40%.

16. Results of the field tests with Calgon M-502 are presented in Figure 1.

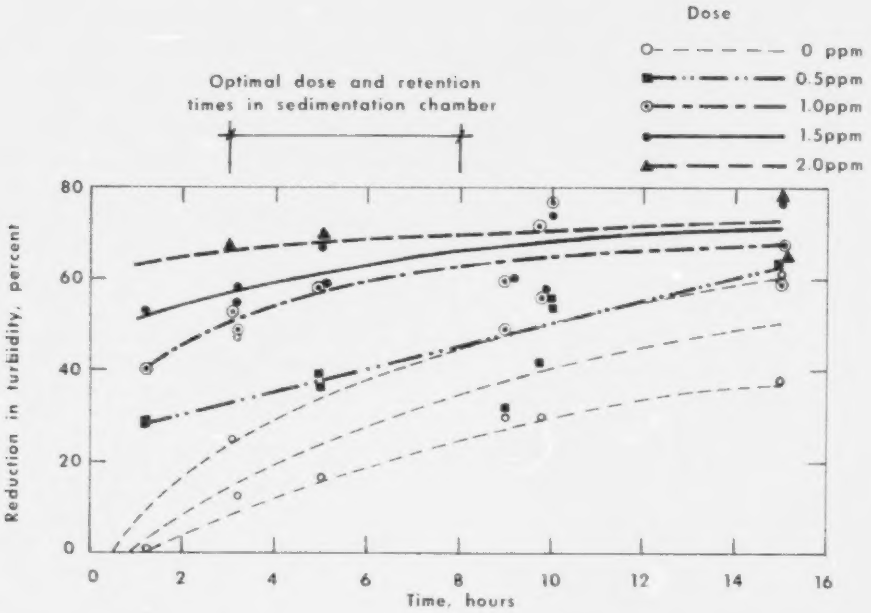


Figure 1. Relationship of the dose of Calgon M-502, the time of retention in sedimentation chamber, and turbidity reduction

SECTION 3

RECOMMENDATIONS

Long term observations into the prevention of water pollution from lignite mines has shown that a major element is the employment of appropriate technologies of drainage and deposit extraction, and the proper waste water management by the mine people. By so doing the quantities of polluted waters and the concentrations of suspended matter there contained could be held to a minimum. Within the mine there should be a division between pure and dirty waters through the employment of dual systems of water intakes and discharges.

In the exploitation of lignite, it is recommended that the levels of particular overburden extraction be appropriate to avoid their location on formations which could produce an increase in the concentration of pollutants that are difficult to remove by water purification. Gradients of permanent or of working benches should be such that the processes of erosion is minimized. For this purpose flumes, ditches and channels draining the mine workings should be lined.

In spite of the implementation of all these actions, a certain quantity of waters requiring treatment will always be present in every mine. With this in mind, recommendations for water purification are hereby presented.

RECOMMENDATIONS FOR THE CHOICE OF TECHNOLOGY FOR WATER PURIFICATION

1. The selection of the water purification method should be preceded by:

   a. Appropriate laboratory investigations. The scope of which should comprise:

      - the full physico-chemical analyses of the mine water
      - analyses of sedimentational properties of the suspended matter
      - results of the analyses and their relevance to the requirements of regulations and standards.

   b. Determination of characteristic values of pure and polluted waters drained from mine, designation of a reliable volume of flow as a basis for overall dimensioning of treatment facilities and the determination of pollution load that will be discharged to receivers.

   c. Analysis of purification methods used on similar waters and the results obtained.

d. Designation of allowable load and concentration of suspensions in purified waters and determination of their influence on the receiver.

2. In the case of mine waters with turbidity less than 100 NTU quantities of suspended matter under 300 ppm with good sedimentation characteristics and zeta potentials of the colloids higher than -30 uV, and where the desired discharge of suspended matter is 30 ppm, it is recommended that purification through natural sedimentation in basins with a retention time of one day be utilized. The shape and dimensions of sedimentation basin should be designed as described in Section 5.

3. In the case of waters described in 2 above but with the necessity to ensure purification to under 30 ppm of suspended matter throughout the year, it is recommended that the sedimentation process be aided with flocculants in accordance with advice given in Section 8.

4. In the case of waters with high turbidity (more than 100 NTU) and with large quantities of finely granulated difficult to settle suspensions, with zeta potential of colloids under the -30 uV, the recommended purification technology is conventional coagulants (alum or lime) or flocculants alone or in combination with conventional coagulants.

5. Before any treatment process is selected, it should be investigated in the laboratory and in complicated cases verified in pilot studies.

RECOMMENDATIONS FOR PURIFICATION WITH FLOCCULANTS

1. It is recommended, that prior to the employment of a basic purification process, waters drained from lignite mines should be subjected to an initial sedimentation in initial sedimentation basins with a retention time of 2-4 hours. Initial sedimentation basins should be adapted to frequent removal of sediments without interruptions to the continuity of the purification process performance.

2. In the case of the purification of waters with suspended matter similar to that presented in this report, it is recommended that the technology of purification based on a process of sedimentation aided with flocculants be used. Cationic polymers with high molecular weights and with properties similar to flocculants of the Calgon M-502 and M-503 type are recommended. The choice of flocculant should be preceded by laboratory tests to establish their usability and optimum doses.

3. Before use the flocculant should be diluted in pure water. Concentration of the solution, time and method of diluting should be determined individually for each flocculant after consultation with the producer. In the case of Calgon M-502 type flocculant a dilution not greater than 0.2%, and the time of diluting the flocculant in water of 7 to 12°C should not be shorter than 2 hours.

4. Dosing the flocculant solution to the water should be done with a piston pump or other apparatus that protects the flocculant from degradation of its flocculating features.

5. In purifying waters with physico-chemical compositions similar to ones in this report, the recommended doses of cationic flocculants of the Calgon type is 0.75 to 1.5 ppm. The size of the dose should be proportional to the suspended matter load of the treated waters.

6. Owing to the influence of fast mixing of the flocculant and water on the effects of purification and utilization of the flocculant, a fast mixing period length of 8-10 minutes is recommended. Prolonging this time to over 10 minutes improves the purification only slightly and from an economic point-of-view may not be profitable. Fast mixing may be either by gravitational or mechanical means or by a stream of compressed air introduced into the water in a special chamber.

RECOMMENDATIONS FOR THE SEDIMENTATION BASIN

1. Sedimentation basin used to remove suspended matter in a process aided with flocculants should consist of two chambers:

   - A chamber of slow mixing with a retention time of at least 20 minutes.
   - A sedimentation chamber providing an average real retention time of 3-8 hours.

   The total number of chambers depends on the quantity of treated water and on the required reserves.

2. Average real velocity of water flow through sedimentation basin should stay within 2-5 mm/sec. limits.

3. Active depth of sedimentation basin should be from 1.2 to 2.4 m. Sedimentation basin should have rectangular shapes, with the length of width ratio of 1:5 - 1:8.

4. Owing to a negative influence of water undulation caused by wind on the effects of water purifying in a sedimentation basin, it is recommended that prior to locating a sedimentation basin, an analysis of the prevailing wind direction be made. On the basis of this analysis the sides of the sedimentation basin should be located in such a way that the direction of the most frequent occurring wind should be parallel to the shorter sides of the sedimentation basin. Independent of the above recommended, the width of the sedimentation chambers should not exceed 40-50 m, and the length 250-300 m. In the case of a longer sedimentation basin, a partition half-way down, distributing uniformly the flow on its whole section, and shortening the run of waves should be erected.

Moreover, to protect against the wind, shields of trees and shrubs should be planted around the sedimentation basins.

5. Construction of the inlet and outlet facilities of the sedimentation basin should ensure minimum turbulence of the incoming and exiting water, and the whole width of the sedimentation basin fed.

6. Sedimentation basins should have a part of its depth assigned for the accumulation of sediment. The size of this part should depend on the proposed frequency of cleaning on the suspended matter concentration and on the type of equipment available to desludge the basin. The depth of sediment accumulation part of the basin should be between 0.8 - 1.5 m.

7. After construction of the sedimentation basin it should be hydraulically tested by tracer methods in order to determine the actual extent of volume utilization. As tracers isotopes (dyes where turbidity is small) with an adequate half-life are recommended. In the case where transit flows or dead spaces are found, appropriate changes and reconstruction (partitions, drifts, shields) in order to remove these unfavorable aspects of the sedimentation basin should be employed.

RECOMMENDATIONS FOR FURTHER RESEARCH

The investigations reported here do not exhaust all the problems connected with the removal of suspended matter from mine waters. Further research of these issues should be undertaken including filtration with plants and flocculation with other more effective chemical substances which without doubt will be developed by the progressive chemical industry. Long term investigations of the influence of synthetic flocculates and other chemical substances exerted in the purification processes when ultimate utilization will be for drinking and industrial purposes. Studies of their influence on biological life within receivers is also needed.

SECTION 4

OBJECT AND THE SCOPE OF RESEARCH

The objective of the research work was the development of technology to purify waters drained from lignite surface mines specifically to reduce the suspended solids to a value below 30 mg/l, with the application of flocculants.

The scope of the research work was comprised of:

a. conceptional work

b. laboratory investigations

c. pilot plant evaluation

The conceptional work consisted of a survey of literature, publications and up-to-date result [illegible] investigations in the following areas: characteristics of waters drained from lignite surface mines, ways of purifying mine waters and the effect of mine waters on the quality of waters in receiving waters. The laboratory investigations were comprised of an analysis of Polish and some American flocculants to remove suspended solids from mine waters. The purpose of these studies were to determine those types of flocculants that provided the best results and under what conditions best flocculation occurred. The field investigations consisted of the construction of an experimental field sedimentation basin at the Adamow mine. The basin was equipped with necessary equipment to carry out hydraulic and technological tests on flocculation and sedimentation. During the field research the two flocculants shown best during the laboratory tests were utilized. Dose rate, different hydraulic conditions in the experimental sedimentation basin and various ways of flocculants solution mixing with mine water were evaluated.

In addition laboratory studies were conducted utilizing sand filters to remove suspended solids. Various different sand granulations, with and without flocculant addition, were evaluated. Work was also performed in the laboratory on the application of gamma radiation processes for the purification of mine waters. This subject will appear in a separate report in 1978.

SECTION 5

INTRODUCTION

GENERAL DESCRIPTION OF LIGNITE DEPOSITS

Lignite deposits in Poland occur at depths from 20 to 350 m. Their exploitation is made by the open pit mining method. A parallel or a fan-wise face advance of the overburden and coal seam is made. Overburden removed initially during exploitation is stacked on an external disposal site. Later an internal area within the worked out open pit working, parallel and at a suitable distance behind the progressing front of coal excavation is used for disposal. The coal extraction and the overburden removal is made with large wheel and chain mining machines, in layers from 10 to 20 m thick. The transportation of overburden as a rule is made with belt conveyors and the coal is transported to the power plant by a combination of belt conveyors and rail haulage. The overburden is composed of quaternary formations, i.e. sands of various granulations, clays, and silts, occurring in different proportions. Lignite however is of tertiary origin, its calorific value ranges between 1900-2000 Kcal/kg. Almost the entire output of lignite is fired in power plants.

SIGNIFICANCE OF THE PROBLEMS OF PURIFYING MINE WATERS FOR ENVIRONMENT PROTECTION

Exploitation of lignite in Poland is always connected with the initial draining of the deposit. Waters flowing into the excavation are from groundwater flows and from precipitation. From the point of view of their physiochemical parameters these flows are divided into two groups: (1) pure waters, coming from wells around the mine system and sporadically also from underground gallery drainage system when these systems have no mining work being performed in its headings, and (2) the polluted waters derived mainly from surface drainage of the excavation and from active underground draining workings.

The pure waters constitute no problem in the wastewater management of mines. Their quality as a rule corresponds to class I of purity and can be discharged directly to receiving streams without special treatment. In some cases waters pumped from wells can contain small quantities of sandy-silty suspensions, which are usually a result of improper selection of well filters or with fractured well casing or shifting of filter tubes. In such cases the suspensions are removed by sand beds with a retention time of 0.5 to 2.0 hours. Sometimes these waters contain certain quantities of divalent iron (Fe^{++}), which after aeration in raceways becomes oxidized and precipitated in the drainage water ditches or in sand beds.

The main problem in wastewater management in lignite mines is the purification of waters belonging to the second group, the so-called "polluted waters" or mine wastewaters. These waters contain suspended particles with diameters of 1 - 10 u. The suspended matter is composed of particles of sands, silt, clays, and coal washed from surfaces of slopes and working benches by rain waters; ground waters drifts, or waters washed from underground draining workings.

The particles are characterized by various shapes, dimensions of grains, and variable concentrations. These factors have an influence on the variability of their hydraulic and sedimentational properties. The sizes of the suspension particles vary from colloids of carbon or clay origin to coarse grains of sands or coal. The shape of suspensions vary from round granules to grains with lamellous shapes, with a considerable surface area in relation to mass.

Concentrations and types of suspensions in the mine waters change both daily and yearly depending on the geological, mining, atmospheric and other conditions. These are discussed in detail later. Waters from lignite mines contain in addition to inorganic compounds also organic compounds (humus), which act as protective colloids imparting brown color, and hindering clarification by means of the sedimentation process. Moreover, mine waters may sometimes contain larger quantities of sodium chloride, calcium and magnesium salts. When the lignite or overburden contain pyrites, e.g., Adamow mine, then the waters draining, particularly from the spoil disposal site, may contain a raised quantity of iron sulfate, which when oxidized forms iron hydroxide.

In summary, the main and often the only pollutant of the mine waters is considerable quantities of suspensions giving the water color and turbidity.

The current practice in purifying mine waters in Poland is the use of large sedimentation basins, the surface of which may approach 22 ha and a total capacity 550 thousand of m^3. Employed theoretical retention times in these sedimentation basins are from 1 to 5 days. The efficiency of the basins is dependent on atmospheric conditions prevailing in the region of the sedimentation basin. The primary problems are the direction and speed of the wind and the levels of pollutants discharged into the sedimentation basins. In favorable atmospheric conditions, reduction in suspended solids in sedimentation basins approached 95%, and concentration in the effluent reaches the 30-40 ppm level. One can assume, that over a year's time, this level of purification was attained 30-50% of the time, i.e., in time of windless days or when the velocity of wind did not exceed 2-4 m/sec. In the remaining time the sedimentation basins operated poorly because the wind caused water movement which resuspended the solids. With wind velocities exceeding 4.0-5.0 m/sec in large sedimentation basins not protected against a wind action, the reduction of suspended solids is minimal and limited to removal of the coarsely grained suspension only.

With the requirements of environment protection getting more stringent in Poland, the necessity arose to increase the effectiveness in the purification of mine waters. Various ways are available to attain this improvement, either through a change in design of sedimentation basins or application of other technologies, such as coagulation, flocculation, filtration, filtration through a complex set of plants or radiation.

The first direction toward improved effectiveness of water purification was the subject of research by Poltegor performed in 1972-73. These studies produced an elaboration of guidelines for the design and construction of sedimentation basins that could help to attain purification to an average of about 30 ppm over a year's time when the waters had a chemical-physical composition similar to waters drained from the Adamow and Konin mines. These waters are fairly representative of the majority of waters drained from lignite mines. In the case of waters with large loads of pollutants, similar to the waters from the Turow mine, and in the case where it was required to reduce the pollutants to a value below 30 ppm, the purification of water by natural sedimentation is not sufficient. This requires application of other techniques, of which the processes of flocculation and filtration were the subject work of research comprised in this report.

New more effective methods of the mine waters purification should provide the following:

1) reduce the land areas required for the construction of purifying facilities

2) increase the level of mine water purification

3) increase the utilization of waters discharged from surface mines for drinking and the industrial purposes.

Another significant issue in the proper purification of mine waters is the large quantity of such waters. Itt is anticipated that even greater quantities will be produced in the future. The general trend is the growth of lignite as a basic power raw material.

PROBLEMS OF THE WATER PURITY IN THE LIGHT OF POLISH REGULATIONS

The quality of waters which can be discharged to surface streams in Poland is regulated by appropriate regulations and dispositions which are updated and amended every few years, always in the direction of increased stringency in the permitted standards of pollutions.

The present obligation in Poland are regulations put into force in 1975[1]. According to the statutes, all the surface waters and reservoirs are divided into three classes of purity. Class of purity depends on a planned assignment of water use at a given flow. The I class waters include water which is intended for drinking water, industry requiring water of a potable quality, and for the breeding of salmon fish species. To the II class belong waters which are designed for fish breeding, to supply the needs of cattle husbandry, to organize spas and to practice water sports. To the III class belong waters assigned to supply industries, excepting industries requiring waters of a potable quality, to irrigate agricultural lands, utilized for gardening and for glass cultures.

For waters of particular classes of purity there are determined appropriate standards of pollution levels, which must not be exceeded in a receiving stream, below the outlet of the wastewaters. Polish standards of permitted pollution levels of inland surface waters are presented in Table 1. The suspended matter does not pertain to periods of sudden water surges.

The current regulations also do not specify clearly the indices of turbidity permitted for the discharge of wastewaters. In practice quantities of pollutants in discharged mine waters are as a rule smaller and are determined each time by relevant bodies of a state administration, which simultaneously perform inspections of quality and quantity of polluted or wastewaters being discharged from particular industrial enterprises.

QUANTITIES OF WATERS DISCHARGED FROM THE MINE DRAINAGE

The quantity of waters discharged from polish lignite mines change in time, dependent on actual hydrogeological conditions of the deposit, on intensity of excavation work. on atmospheric conditions and on many other factors, that effect the inflow of underground or surface waters.

Average, quantities of waters drained from several lignite mines are specified in Table 2. As can be seen in the table, polluted waters from lignite mines make up about 60-90% of the water, while in mines now under construction they make up only 20-30% of the discharged waters. This reduction is due to new design of the well system for drainage of the lignite deposits of Belchatow and of Legnica. The quantity of discharges from Polish mines falls within 1:1 - 1:10, comparing favorably with the East German Democratic Republic of 1:6 - 1:16.

CHARACTERIZATION OF WATERS AND OF SUSPENDED MATTER DRAINED FROM LIGNITE SURFACE MINES

Chemical composition of waters drained from lignite surface mines is approximately the same as the ground water quality of the region being mined. The chemical quality of the water as a rule does not exceed the permitted levels of class I or II waters (Table 1). Some more important parameters of mine water are presented in Table 3. As seen in the table, the main pollutant is the high suspended matter concentration and the associated turbidity. As already mentioned, the quantity of suspensions is variable within very wide

TABLE 1. STANDARDS OF PERMITTED POLLUTIONS IN INLAND SURFACE WATERS
R/RM 29 of November 1975, Dz. U. (Official Gazette) No. 13.XII.1975

Indices of Pollutants	Concentration units	Classes of Purity I	II	III
Dissolved oxygen	ppm of O_2	6 & above	5 & above	4 & above
BOD_5	- " -	4 & less	8 & less	12 & less
Permanganate oxygen consumption	- " -	10 & less	20 & less	30 & less
Bichromate oxygen consumption	- " -	40 & less	60 & less	100 & less
Chlorides	ppm of Cl	250 & less	300 & less	400 & less
Sulfates	ppm of SO_4	150 & less	200 & less	250 & less
Total hardness	mval/l	7 & less	11 & less	14 & less
Dissolved substances	ppm	500 & less	1000 & less	1200 & less
General s.s., sudden water surges excepted	ppm	20 & less	30 & less	50 & less
Temperature^x	^oC	22 & less	26 & less	26 & less
Smell		V & less	natural	very weakly specific at most
Color^{xx}	ppm of Pt.	natural		
Radioactive substances	in determined quantities in separate regulations			
pH values	pH	6.5-8.0	6.5-9.0	6.5-9.0
Ammonia nitrogen	ppm N_{NH_4}	1.0 & less	3.0 & less	6.0 & less
Nitrate nitrogen	ppm N_{NO_3}	1.6 & less	7.0 & less	15 & less
Organic nitrogen	ppm N_{org}	1.0 & less	2.0 & less	10 & less
Total iron	ppm Fe	1.0 & less	1.5 & less	2.0 & less
Manganese	ppm Mn	0.1 & less	0.3 & less	0.8 & less
Phosphates	ppm PO_4	0.2 & less	0.5 & less	1.0 & less
Rhodanates	ppm CNS	0.02 & less	0.5 & less	1.0 & less
Cyanides, fixed cyanides excepted	ppm CN	0.01 & less	0.01 & less	0.05 & less
Fixed cyanides	ppm Me/CN/x	1.0 & less	2.0 & less	3.0 & less
Volatile phenols	ppm	0.05 & less	0.01 & less	0.05 & less
Detergents (substances surface active)	ppm	1.0 & less	2.0 & less	3.0 & less
Oils	ppm	lack of visible traces on water faces		
Substances extracted with petroleum benzine	ppm	5.0 & less	15 & less	40 & less
Lead	ppm Pb	0.1 & less	0.1 & less	0.1 & less
Mercury	ppm Hg	0.001 & less	0.005 & less	0.01 & less
Copper	ppm Cu	0.01 & less	0.1 & less	0.2 & less
Zinc	ppm Zn	0.01 & less	0.1 & less	0.2 & less
Cadmium	ppm Cd	0.005 & less	0.03 & less	0.1 & less
Chromium 3+	ppm Cr	0.5 & less	0.5 & less	0.5 & less
Chromium 6+	ppm Cr	0.05 & less	0.1 & less	0.1 & less
Nickel	ppm Ni	1.0 & less	1.0 & less	1.0 & less
Total of heavy metals	ppm	1.0 & less	1.0 & less	1.0 & less
Silver	ppm Ag	0.01 & less	0.01 & less	0.01 & less
Vanadium	ppm V	1.0 & less	1.0 & less	1.0 & less
Boron	ppm B	1.0 & less	1.0 & less	1.0 & less
Arsenic	ppm As	0.05 & less	0.05 & less	0.2 & less
Free chlorine	ppm Cl	undetectable		
Fluorine	ppm F	1.5 & less	1.5 & less	2.0 & less
Sulfides	ppm S	undetectable		0.1 & less
Acrilonitrile	ppm	2.0 & less	2.0 & less	2.0 & less
Caprolactam	ppm	1.0 & less	1.0 & less	1.0 & less
Coli titre of faeces type		1.0 & above	0.1 & above	0.1 & above
Pathogenic bacteria		undetectable		
Biologic tests with fish	24 hours	positive--fish should not die in water in 24 hours		

TABLE 2. DISCHARGE QUANTITIES FROM LIGNITE MINES

Name of Lignite Mine	Quantity of Drained Waters in m^3/min		
	Total	Pure Waters from Wells	Polluted Waters from Working and from Drainage Systems
Adamow	25	9.4	15.6
Patnow	80	10	70
Jozwin	40	7	33
Kazimierz	50	7	43
Turow I and II	37	6	31
Belchatow (proj.)	200-500	150-400	50-100/185^x
Legnica (proj.)	130^x	80	20/70^x

x = value together with precipitation waters
proj. = projected

limits. Investigations of the suspension concentration in various places within the workings of the Turow, Patnow, Kazimierz, Jozwin, and Adamow mines did not show a relationship to exist between the quantity of suspended matter and the geological, working and atmospheric factors of the mine. The highest contents of suspensions appeared in the waters from the Turow II mine, and the lowest in mines of the Konin region. In predicting the quality of waters to be drained from newly designed mines one can assume that the quality will be similar where the geological conditions are similar. Mines in the Adamow region should have an average quantity of suspensions of about 180-220 ppm, while those in the region of Konin should be within the limits of 100-150 ppm.

The suspension consists of mineral and organic matter. Mineral suspended matter is composed of sand, dust, and clay grains washed from the surfaces of the floor, slopes and overburden benches of the mine and from slopes and horizons of stacked overburden material in the working. Organic suspension on the other hand are composed of various sized particles of coal coming from the floor and from coal levels, and occasionally from underground active draining galleries (headings). Electric potential of colloidal particles have been found to be -20 uV for the suspensions from the mines Adamow and Konin, and approaching -70 uV for the suspensions from the Turow mine.

Investigations at the Wroclaw Technical University[2] have shown that 53-88% of suspended matter in waters sampled at the Konin and Adamow mines were composed grains with diameters greater than 10 u, and the number Re > 2.6×10^{-4}. Sedimentation analysis of water from the Konin mine indicated that the suspended sedimentation did not show any Brownian movement interferences during the first 16 hours. The particles remaining in the suspensions after 16 hours showed clear interferences caused by electrical charges.

Re - Reynolds number.

TABLE 3. TYPICAL QUALITY OF WATERS DISCHARGED FROM LIGNITE MINES

					Konin		
Pollutant	Unit	Turow I	Turow II	Adamow	Open Pit Patnow	Open Pit Kazimierz	Open Pit Jozwin
BOD_5	ppm O_2	0.8-4.2	1.2-2.0	1-40	-	-	-
COD	ppm	3-36	22-600	64-390	8-52	10-55	-
Chlorides	ppm Cl	27-42	16-52	20-100	tu 13	tu 14	tu 13
Sulfates	ppm SO_4	270-480	204-350	50-150	tu 40	tu 10	tu 18
Dissolved substances	ppm	650-1050	560-1000	tu 600	270-500	tu 500	tu 600
Total S.S.	ppm	tu 1000	20-7500	60-2800	44-400	73-370	tu 350
pH	-	7.5-8.1	7.0-8.1	7.0-8.1	7.0-8.0	7.6-8.3	7.0-8.0
Total iron	ppm	0.01-2.0	0.07-3.0	0.0-5.0	tu 2.0	tu 1.0	tu 0.7
Color	ppm	10-30	30-90	15-20	3-50	10-45	tu 30
Turbidity	ppm SiO_2	10-1000	to not transp.	10-not transp.	5-500	30-50	10-not transp.

In water samples taken from the Konin mine the Brownian phenomenon occurred after 20 hours of sedimentation. Results of Andreassen analyses showed that only fractions of suspensions with $Re > 10^{-4}$ will settle and their sedimentation speed can be calculated using Stokes formula.

One could assume that also a portion of suspensions with $Re > 10^{-5}$ will settle, as some have only a small mobility. The remaining $Re > 10^{-5}$ particles will not settle and in order to settle them it is necessary to use coagulants or flocculants.

CHARACTERIZATION OF SEDIMENTS

The character of the suspensions entrained in water discharged from lignite mines and the efficiency of sedimentation basins can be partially determined by characterization of the quality and composition of the sediments deposited in the sedimentation basins. For this reason in 1976 an analysis was performed of sediment samples collected from the sedimentation basin "Struga Biskupia" from the Konin mine. The samples were taken from the bottom of the basin under the water in sections perpendicular to the direction of flow in the sedimentation basin, and at the following distances from the inlet: 40, 100, 160, 235, 335, 480 and 630 meters. Particle size composition of sediments taken from particular sections is given in Table 4, and specific gravity in Table 5. The data showed that the larger size particles were removed near the inlet, while the particles near the outlet were predominantly of the smaller sizes. The particles near the inlet had a greater specific gravity than those near the outlet.

TABLE 4. PARTICLE SIZE ANALYSIS OF SEDIMENT FROM STRUGA BISKUPIA SEDIMENTATION BASIN AND PARTICLES OF A GIVEN FRACTION IN SAMPLE SPECIFIED, IN %

Distance from Inlet(meters) Size of fraction particles	40 m	100 m	160 m	235 m	335 m	480 m	630 m
0.6 mm	18.1	9.8	11.3	8.0	7.2	5.2	6.3
0.385-0.6 mm	8.6	13.4	12.7	8.6	9.8	10.7	8.1
0.25 - 0.385 mm	16.7	15.1	18.5	5.6	13.3	15.9	13.3
0.102-0.25 mm	18.9	28.7	25.7	32.5	19.5	18.5	17.8
0.075-0.102 mm	20.5	16.3	12.3	14.4	29.3	28.1	24.5
0.075 mm	16.6	15.8	18.7	30.7	20.1	21.5	30.0
Total	99.4	99.1	99.2	99.8	99.2	99.9	100.00

TABLE 5. SPECIFIC GRAVITY OF SEDIMENTS FROM "STRUGA BISKUPIA SEDIMENTATION BASIN

Distance from Inlet (meters) Size of fraction particles	40 m	100 m	160 m	235 m	335 m	480 m	630 m
0.6 mm	1.73	1.71	1.72	1.57	1.58	1.53	1.50
0.385-0.6 mm	1.82	1.76	1.75	1.55	1.53	1.51	1.53
0.25-0.385 mm	1.84	1.71	1.75	1.64	1.70	1.55	1.60
0.102-0.25 mm	1.75	1.90	1.67	1.68	1.63	1.59	1.58
0.075-0.102 mm	1.87	1.95	1.82	1.70	1.77	1.61	1.64
0.075 mm	1.93	1.93	1.90	1.69	1.76	1.60	1.59

METHODS USED TO TREAT WATERS DRAINED FROM LIGNITE SURFACE MINES

The treatment of mine waters is limited to the reduction of excessive amounts of total suspended solids in order to meet required effluent regulations. The first step of suspended solids reduction takes place in the reservoirs or galleries situated near the dewatering pumping stations. Further reduction of the more difficult sediment suspensions takes place in reservoirs, natural ponds, or artificial sedimentation basins constructed on the land surface outside the pit or at the bottom of open pits. In the sedimentation basins the reduction of suspensions is by way of sedimentation and partly of spontaneous coagulation.

In 1964-65 tests were performed to treat mine waters from the mine Kazimierz by means of hydrocyclons. The results were not satisfactory, and no use of this method for practical purposes are contemplated.

Total area of land utilized for sedimentation basins by lignite surface mines in Poland amounts to about 60 ha, and in the near future it is anticipated that 120-150 ha of arable land further will be needed for sedimentation basins for new mines, and about 50 ha for construction of more basins for existing mines. In Table 6 typical parameters and effects of the four largest sedimentation basins constructed in lignite mines are presented.

REVIEW OF RESEARCH WORK AND PUBLICATIONS CONNECTED WITH THE PURIFICATION OF THE LIGNITE MINE WATERS

The research work and publications connected with the purification of waters drained from lignite mines can be divided into the following three subject groups:

1. Research connected in particular with reconnaissance of the physical-chemical composition of mine waters, and with hydraulic and technical characteristics of the suspensions contained in these waters.

2. Studies connected with the determination of the most effective and most economical technology of purification.

3. Investigations connected with the determination of influence of mine waters on the physico-biochemical parameters of the receiving streams.

The majority of the up-to-date research has not been published and is utilized in project work and in the development of the treatment facilities. The early studies concerning the issues of quality and ways of treating drainage waters were made in 1955 on waters drained from the then active surface mine Goslawice in the region of Konin[3]. On the basis of laboratory analyses of prepared samples of water with a coal and dusty - clayey suspension it was determined, that the retention time necessary for these waters to obtain the required reduction of suspensions was four days. The results of these tests were for a long time the basis for designing treatment facilities in the

TABLE 6. CHARACTERISTICS OF THE FOUR LARGEST SEDIMENTATION BASINS AT LIGNITE MINES

Name of sedimentation basin and year of construct.	Name of surface mines	Average inflow m^3/min	Area of sedimentation basin ha	Sedimentation basin current capacity thousands of .m^3	Average depth m	Theoretical time of retention days	Conc. of suspensions inlet ppm	Suspension concentration - outlet ppm	Average reduction susp. %
Struga Biskupia 1960 r.	Patnów (Konin)	20	10	123 + 126	2.50	4.3	60-120	20	67-84
Rów glówny 1967	Patnów (Konin) Józwin (Konin)	98	21.1	210	1.00^x	1.5	100-200	30-60	65-70
Teleszyna 1968	Adamów	17	7.8	170	2.20	7^{xx}	180-250	10-20	90-95
Sedimentation basin by shaft	Kazimierz kop. Konin	20	6.8	87	1.45	1.3	350	33	92

x - provisional depth, ultimate depth will be about 2.20 m

xx - in relation to the expected inflow of about 1.5 day rate lignite industry. In the subsequent years a number of studies were made concerning the influence of drained mine waters on the surface receivers[4,5,6,7]. These were made for the benefit of lakes situated in the region of the Konin mines. In these studies a number of physico-chemical analyses of waters drained from the lignite mines Goslawice, Patnow and Kazimierz were performed. The efficiency and the effects of the first field sedimentation basins constructed at a lignite mine was also evaluated. The results of these studies showed the water quality to be within the values shown in Table 3.

In 1965 physico-chemical and technological tests of mine waters drained from lignite mines of the regions of Konin, Turow and Adamow[2] were carried out. On the basis of investigation of the sedimentation of suspended matter conducted in the laboratory, new directives were provided regarding the sizing of sedimentation basins. Recommended retention time of the mine waters in the sedimentation basins was 24 hours, and the surface hydraulic load was 1.2 m^3/m^2 per day. In the report it was concluded that these design factors would cause the retention in the sedimentation basins of particles with a settling rate equal to or larger than 1.3×10^{-3} cm/sec., which corresponds to a Reynold number $Re = 1 \times 10^{-4}$. On the basis of these investigations a number of sedimentation basins was designed and constructed for the purification of lignite waste waters and are working to this day.

Between 1971-73 surveys were carried out of the existing field sedimentation basins of the Konin and Adamow mines to evaluate the characteristics of the flow of water through the sedimentation basins and to determine the distribution of suspensions concentration within the basins[8,9]. These surveys were based on a simultaneous measurement of actual time of water flow through the sedimentation basins with the help of isotope tracers and on determination of suspension concentration in particular measured sections. The results of this survey was as follows:

1. The major suspended solids reduction in the constructed sedimentation basins was taking place in the inlet portion of the basins in an area not exceeding 30-40% of the basins' entire area. The remaining basin areas had an insignificant effect in the reduction of the suspension concentration.

2. In the processes of gravitational sedimentation in large field sedimentation basins, waters similar to waters from the mines of Konin and Adamow can be treated to a suspended solids concentration of about 30 ppm.

3. The effect of purification in field sedimentation basins depends chiefly on force, direction, and velocity of winds prevailing in the regions of the sedimentation basins. In case of occurrence of winds with velocity exceeding the 4.0 - 5.0 m/sec, resuspension of the suspended solids in the sedimentation basins takes place by the effect of wave action. The general effectiveness of the sedimentation basin is then small.

4. The average active basin capacity amounted to 30-50% of their entire capacity, and a velocity of flow within the basins of 2.0-6.0 mm/sec.

5. The flow velocity within the sedimentation basins had a significant lack of uniformity. Local velocities of flow in particular portions of the investigated sedimentation basins differed considerably, from 0 mm in no flow areas to about 60 mm/sec. in the inlet regions.

On the basis of results of the above studies a new type of sedimentation basin was devised for the purification of mine waters, in which the polluted waters was to be retained 16-20 hours with a planned reduction of suspended matter to 30 ppm, the standard. This value may not be obtained under adverse atmospheric conditions.

The problems of purification of waters drained from lignite mines by way of sedimentation, and problems of water flow hydraulics in the sedimentation basins were presented in a number of publications[10,11,12,13]. These publications among other things state the requirements, which should be met by the inlet and outlet arrangements of the sedimentation basin, in order to achieve the highest rate of surface volume utilization of the basin.

Investigations of hydraulic efficiency of the waste water treatment facility have been performed on full scale installations in other industries using isotope tracers. A number of Dorra type[14] sedimentation basins and rectangular multi-chamber[15] sedimentation basins purifying industrial wastes have been tested. These tests have shown the suitability of the isotope tracers for studying the hydraulic characteristics of basins. The results of these studies have been used to modify the physical arrangements of the sedimentation basin or tank to obtain better purification. Isotopic tracers have been used in investigations of the sedimentation processes[16] associated with bituminous coal.

Apart from isotopes a number of other tracers have been employed in investigating the hydraulic efficiency of treatment facility such as solutions of sodium chloride[17,18], and fluorescein dyes[19,20]. In tests of model sedimentation basins dyes[20,21] and solutions of salts and acids[22,23] have been used as tracers. On the basis of the information received the best results were obtained with isotopes, the fluorescein, the rodanine B, and the ions of lithium were used as tracers[24,25,26].

An important assignment in testing the hydraulic parameters of sedimentation basins is the appropriate methodology for conducting the research and interpreting the acquired results. There are two methods of testing the reservoirs by means of a traced wave of flow:

-the method of a Variable wave of flow obtained by introducing to the water a determined quantity of tracer during a short period of time in relation to the time of flow of water through the sedimentation basin;

-the method of continuous wave of flow based on dosing tracer with a constant intensity, till constant concentration appears at the outflow[27].

Owing to the large dimensions of the sedimentation basins used to purify waters coming from lignite mines, the method of variable wave of flow was adopted. Interpretation of results acquired with the use of this method is a subject of many publications[21,22,23,28,29,31,32] and will be presented in detail in the ensuing part of this report. The results are usually presented in a so-called "chart of the flow wave," illustrating the concentration of tracer as function of time in appropriate section or on outlet of a purifying facility. Such a graph affords primarily a determination of the character of flow going through the sedimentation basin. One can distinguish here two basic types of flow, the so-called piston flow and the perfect mixture flow. The piston flow is most desirable in sedimentation basins, however, it never appears by itself, that is, it is always accompanied by a certain amount of perfect mixture flow and by the existence of dead spaces. Wolf and Resnick[31] and other authors discern also a so-called "short circulating," defined as portion of flow with infinite velocity, or a zero time of retention.

Interpretation of the Flow curve can be by the traditional manner, where the basic characteristic parameters are the central values of the curve, or with new methods[31], where the whole of the curve is considered. Both methods provide an analysis of the efficiency of a sedimentation basin under test, the proportion of its active volume, the dead spaces, the degree of flow disturbances, etc.

On the basis of the above publications it can be concluded that each sedimentation basin prior to its use should be investigated for its flow hydraulics. Results of these investigations should be used to modify the execution of such adjustments of sedimentation basin, so as to secure a maximum capacity utilization.

The acquisition of data on water purification with the aid of sedimentation in large sedimentation basins requires a comprehensive analysis of water quality, of atmospheric conditions in the region of the sedimentation basin, the selection of appropriate shape, dimensions of all elements of the sedimentation basin, a penetrating analysis of the necessary time for retention and the determination of the proper surface hydraulic loading and the application of adequate protection shields against the effects of wave action. Only correctly constructed sedimentation basins can produce the wanted results, i.e., the suspension reduced to the 30 mg/l level.

In some lignite mines (Turow) it is particularly difficult to purify the waters and more intensive processes of purification are required. These waters were a subject of laboratory tests with the application of coagulants utilizing conventional chemical substances. Also undertaken were laboratory scale tests of purifying the mine waters from the Turow mine by means of electrocoagulation[33] with some positive results recorded. Early tests on the application of filtration under laboratory conditions gave positive results in some cases[34,36].

The first laboratory investigations utilizing the application of traditional coagulation were performed in 1964[7] with waters from the Konin area mines. As a coagulant aluminum sulfate was used in doses of 30-100 ppm (average 50 mg/l). The treated water after 2-hours sedimentation in a cylinder was clear and lightly opalic. The oxygen demand was decreased to 4 ppm of O_2. With waters containing oxygen demand above 200 ppm O_2 the reduction in oxygen demand was smaller, nonetheless it decreased down to 28 ppm of O_2. The content of iron and manganese in waters treated with alum fell to the trace level. Changes in the acidity or alkalinity of the water did not have a marked influence on the effect of coagulation.

In 1962 investigations were conducted with waters from the Goslawice mine (region of Konin) in which the mine water was mixed with an ash slurry from the power plant[35]. This combination gave positive results, ensuring fast and effective sedimentation of suspensions. This method however has not found wide application due to the large water requirement by the power plant, where as a rule closed circuit systems in the hydraulic transportation of ashes are practiced and also due to the rise in pH of the treated waters to over 9.0 and an increase in hardness.

Further laboratory tests on the application of coagulation were made in 1968 on the mine waters from the Turow mine[36]. Used for the tests were the following coagulants:

- bentonite
- fly ash from Turoszow power plant
- lime CaO
- sulfuric acid H_2SO_4
- aluminum sulfate $Al_2(SO_4)$ 18 H_2O.

The coagulant was added to a water sample during rapid mixing, which lasted for 3 minutes, and then was maintained at slow mixing for 20 minutes which was followed by sedimentation for 2-24 hours. Results obtained from these investigations provided the following conclusions:

1. Bentonite did not exert any influence on the acceleration of the purification process and is not suitable as coagulant for waters drained from mines.

2. Ashes from the power plant "Turoszow" did not have a positive effect as a coagulant.

3. The sulfuric acid was a successful coagulant when used in very large doses, but the pH was decreased to a level inadmissible for discharge to surface waters.

4. Coagulation with lime water in a quantity of about 120 ppm of CaO gave positive results. A dose of lime water in quantity of about 120 ppm of CaO and a 2-hourly sedimentation caused a significant reduction in the COD in waters down to about 5 ppm of O_2 and the color from 200 to 30 ppm of Pt, and maximally from 2000 to 30 ppm of Pt.

5. Coagulation of water with aluminum sulfate also gave positive results. A dose of this coagulant in the amount of 150 ppm and a 24-hour sedimentation period reduced the quantity of suspended solids and the chemical oxygen demand down to values admissible for waters to be run off to the surface receivers.

However the results of these investigations were not put to use owing to the large amounts of coagulants necessary for the purification of the mine water, 30-150 m^3/min.

Further laboratory investigations of the application of coagulation were begun in 1972[34]. The tests were carried out on strongly polluted mine waters of the Turow mine. The process of volumetric coagulation was carried out in vessels of 1 liter capacity employing 2 minutes of fast mixing and 20 minutes of slow mixing. After the completion of mixing, the water was subjected to sedimentation for the period of 1 hour. The effect of coagulation was evaluated by the measurement of color, turbidity and oxygen demand. In the tests the basic coagulants used were aluminum sulfate, iron sulfate and calcium and as aids were used edible gelatin, colloidal silica, fine sand, starch flocculant P-26 and synthetic flocculants of polish production, the Gigtar, and the Rokrysol WF-1. These aids were dosed either, simultaneously, or ahead of, or behind in time in relation to the dosing of basic coagulant. The usability of mixed coagulant was also considered (aluminum and iron sulfates).

Two types of water, one with average and the other with high levels of pollution, were tested. The best results with water having an average level of pollution, (turbidity to 100 ppm, color to 30 ppm of Pt. oxygen demand to 18 ppm of O_2), were achieved using aluminum sulfate with Gigtar added as an aiding substance. The dose of $Al_2(SO_4)_3 \cdot 18 H_2O$ was 100 ppm and Gigtar 1 ppm. It was found that the timing of the addition of the aiding substance was critical. Optimum time of Gigtar dosing was 3-4 minutes ahead of the basic coagulant or 10 minutes after dosing the basic coagulant. Under these conditions the turbidity was reduced 90-100%.

The other combinations of coagulant and aiding substances when used in large doses also gave good results, but not as good as that quoted above. In the case of strongly polluted waters, where the turbidity approached 1000 ppm and oxygen demand was up to 600 ppm of O_2, good results were acquired when lime was used and then recarbonizing the water and employing a coagulant mixed with aiding substances such as the active silica, and edible gelation. The lime was added to the mine water in the form of a lime water in dosages of 100-600 ppm of CaO. Positive results also were obtained employing contact coagulation followed by filtration through a filtering bed with granulations

1.5-2.0 mm diameter. From the practical standpoint of employing the results of the above tests to full scale mine water purification, it was seen that although some of these tests resulted in an almost 100% purification of the strongly polluted waters, the large doses of coagulates required and the necessity to use sometimes several chemical substances would be troublesome to employ and comparatively costly.

An important problem from the point of view of environmental protection is the determination of the effect of mine waters on the chemical composition and the biocenosis of receiving bodies of water. Early research efforts in this field were conducted in 1960[4]. The influence of waters drained from the Konin region mines on lake Goslawickie and Patnowskie were studied to determine:

- the reach of the sediment entrained in the mine waters
- the influence and extent of inflowing waters on the composition and the biocenosis of water in the lakes
- the necessary level of the mine water purification, to minimize the harmful effects on the waters of the lakes.

The investigations showed that mine waters draining into the lakes with small quantities of colloidal suspensions of difficult to remove sediment were to a small extent increasing the turbidity in the first Goslawickie lake. It was found that on the whole the effect of mine waters on the composition and the biocenosis of lake waters was small, and limited as a rule exclusively to the lake to which mine water was directly discharged after their purification in sedimentation basins.

The mine waters were causing some small beneficiation to the lake waters because of their nutritious salts, which contribute to more intensive overgrowing of the lakes and to the increase in organic contents of the lake. The investigations have shown, that from the point of view of preserving proper composition of waters and biocenosis in the direct receiver, which was lake Goslawickie, the purification necessary for the mine waters was the reduction of suspended solids only. Further investigations were carried out in 1961-62[5], and the conclusions were approximately the same.

Subsequent investigations in 1965-66[6], confirmed the minimal effects of mine waters on the chemical composition and the biocenosis of lakes as receivers. It was found in these investigations, that a quantity of biogenic substances was inflowing into the lakes together with mine waters and their concentration in 1966 was determined to be 0.68 ppm of N, (NH_4), 0.38 ppm of PO_4, and about 27 ppm of SiO_2. The load of these substances was increasing with the amount of mine water discharges. A comparison of the water composition in the lake in the course of a 5-year period, 1961-1965, had shown that in this time a small rise in the biogenic substances had occurred as seen by an increase in the quantities of plankton and vasculous plants.

Other research was conducted on the influence of waters drained from the surface mine Turow on the receiver - Nysa Luzycka river. This analysis was carried out by Poltegor in 1969[37]. It was shown that mine waters had impact on the river as noted by the increased concentration of suspended solids during low flow periods in the river, surpassing the allowed quantity of pollution. At higher flow levels, the influence of mine waters was small. The investigations did not include an analysis of the mine water influence on the biocenosis of the river.

In summary the above survey of publications and research studies has shown that at the present time a wide range of problems connected with the purification of mine waters have been investigated particularly with the application of the sedimentation process. Also, the processes of coagulation with the use of conventional coagulants has received attention. However the application of synthetic flocculants as separate, self-contained and basic substances, of radiation influence on the process of water purification, or the detailed studies of filtration have not been analyzed. The technology of purifying waters with the aid of synthetic flocculants is widely employed in purifying sewages and industrial waste waters, especially in the U.S.A., where more than 130 flocculants of all kinds are produced. In Poland flocculants are used mainly to purify waters derived from plants of mechanical processing of coal and from ore beneficiation plants. In 1972, 22 mines of bituminous coal production used flocculates for the purification of waters coming from processing plants, utilizing about 400 tons of flocculants annually, mainly of the starch type[38]. From the current literature and publications from both Poland and the U.S.A. it is apparent that radiation and filtration are not used to purify waters drained from surface coal mines.

The use of coagulates or flocculates is not employed in the surface mines in the U.S.A. with the exception of the Centralia mine operated in the State of Washington. Here runoff water polluted with suspended matter is purified in a sedimentation basin using as the flocculant Nalco 634 in quantities of about 10 ppm or Super Floc 330[39].

Other publications dealing with the application of coagulants, and flocculant, research methodology and sedimentation are presented as references 40 to 48.

SECTION 6

LABORATORY INVESTIGATIONS OF FLOCCULANT APPLICATION

GENERAL CHARACTERIZATION OF THE SURFACE MINES, FROM WHICH WATER SAMPLES FOR TESTS WERE TAKEN

Water samples were collected from the Turow II, Konin and Adamow mines. Water was sampled directly from the outlets of the pumping station pipelines. Tables 7 and 8 present the general characteristics of the three mines and their overburden. The Turow II mine had an average of 10-15 m^3/min of discharge water containing on the average 900-1100 ppm (max. - 7,500 ppm) of suspended matter. Initial drainage of the Adamow deposit was accomplished with a well system. Precipitation and seepage waters flowing into the workings were conveyed to the lowest part of the working and pumped from there to the "Teleszyna" sedimentation basin. The average quantity of water drained was 25 m^3/min.of which 15.4 m^3/min were polluted water with an average suspended matter content of 100-250 ppm. The Patnow pit is drained with the aid of wells and underground drainage galleries. Seepage and rain water are conveyed with a network of ditches to the lowest point of the working where together with the mine draining headings are pumped to the sedimentation basin "Row Glowny."

TABLE 7. CHARACTERISTICS OF SURFACE MINES USED IN STUDY

Area (hectors)	Turow II Mine	Adamow Mine	Konin Mine Patnow Pit
Internal spoil disposal	0	236	350
Bottom of workings	50	111	54
Slopes and levels of uncovered coal	127	58.5	8
Overburden slopes and levels	403	87	83
Adjacent terrain	60	309.5	160
Total catchment area	640	802	655

TABLE 8. COMPOSITION OF OVERBURDEN ROCKS OF STUDY MINE

Percent	Turow II Mine	Adamow Mine	Konin Mine-Patnow Pit
Sands and gravels	12	35	56
Clays	77	64	18
Other	11 (5-10%coal)	1 (%coal)	1 (%coal)

GENERAL CHARACTERIZATION OF INVESTIGATED MINE WATERS

The physico-chemical composition of the waters investigated was determined in accordance with Polish methods. The results of the analyses are specified in tables 9-11. Mine waters are characterized with high and very high turbidity, a large quantity of suspensions and with increased oxygen demand. In addition to these parameters these waters had a raised content of iron, whereas the manganese appeared in trace amounts only. The remaining indices of chemical composition did not exceed the permitted values for the class I or II (Table 1) surface water purity.

In the period of time under investigation the turbidity in the mine waters of Turow II fluctuated from 250 to 1000 ppm, the quantity of suspensions from 437 to 6300 ppm, the oxygen demand from 28 to 40 ppm of O_2, iron to 3 ppm of Fe, sulfates up to 340 ppm of $SO_4^=$.

The mine water of the Konin - Patnow open pit during the period of investigation was characterized with turbidity about 300 ppm, with quantity of suspensions - 250 - 472 ppm, oxygen demand - 14-22 ppm of O_2, the iron quantity did not exceed the 3 ppm.

The mine water of the Adamow open pit during the time considered had turbidity of 250-600 ppm, suspensions - 124-356 ppm, oxygen demand of 13-80 ppm of O_2, iron - 2-8 ppm of Fe.

The data showed that the Turow II open pit had the poorest quality water. The data also showed that a relationship existed between turbidity and suspended solids (Table 12). This relationship is shown in Figure 2. The directional coefficients of straight lines for the Adamow waters was 1.5; for Konin waters 0.6; for Turow waters 0.075. The character of dependence of Turow raw water is the same, only the straight line is moved parallel in relation to the straight line after 2 hours of sedimentation. In later tests it was shown, that with a smaller value in the directional coefficient of straight lines the removal of suspensions and turbidity became progressively more difficult.

LABORATORY TESTS OF FLOCCULANT APPLICATION

Investigations of coagulation were performed in test of 1 dm^3 volume on a six-stand coagulator. Fast mixing with a velocity of 80 rev/min lasted in the first stage of tests for 2 minutes, and the slow mixing with the velocity of 20 rev/min for 20 minutes. The same was true for all types of flocculants, anionic, non-ionic and cationic.

Polyelectrolites were dosed as water solutions with concentrations from 0.05 to 0.5%, while the remaining chemicals, as 1-5% water solutions.

TABLE 9. PHYSICO-CHEMICAL COMPOSITION OF MINE WATERS
TUROW II MINE

Parameter	Units	Test 1 2/18/75	Test 2 3/3/75	Test 8 7/75
Turbidity	ppm	1,000	1,000	600
Color	ppm of Pt.	15	20	
Smell		Veg 1	Veg 1	Veg 1
Reaction	pH	8.3	7.6	7.7
Basicity	mval/dm^3	F 0.1		
		M 3.8	3.6	3.7
Hardness	degree	20.5	13.1	13.0
Calcium	ppm Ca	78.4	47.0	90
Magnesium	ppm Mg	40.4	27.8	22
Chlorides	ppm Cl	22.0	25.0	30
Manganese	ppm Mn	n.o.	n.o.	n.o.
Total iron	ppm Fe	n.t.	3.0	1.15
Ammonia	ppm N	n.t.	n.t.	0.4
Nitrites	ppm N	n.t.	n.t.	0.2
Oxygen Demand	ppm O_2	32	20.0	23.0
Sulfates	ppm SO_4	214	346	109
Dissolved Solids	ppm	817	783	1103
Mineral	ppm	760	683	950
Volatile	ppm	57	100	158
Suspensions	ppm	6313	5795	437
Mineral	ppm	4274	3953	347
Volatile	ppm	2039	1842	90
Carbonate hardness	degree	10.4	10.1	10.4
Noncarbonate	degree	10.1	3.0	2.6
Temp. of water sampling	°K	274.0	277.0	
Potential	uvolt	-23	-45	-26.5

After the process of flocculation and sedimentation for 20 to 30 minutes analyses were made for color, turbidity, basicity, reaction, and oxygen demand. In some cases the analysis was supplemented with the determination of hardness and iron.

An additional inspection of the process was made denoting the value of electrokinetic potential. The electrokinetic potential was determined on the basis of measurement of electrophoretic particles movement, which was determined with a zetameter. Both the colloidal particles of raw water and the coagulated particles were measured.

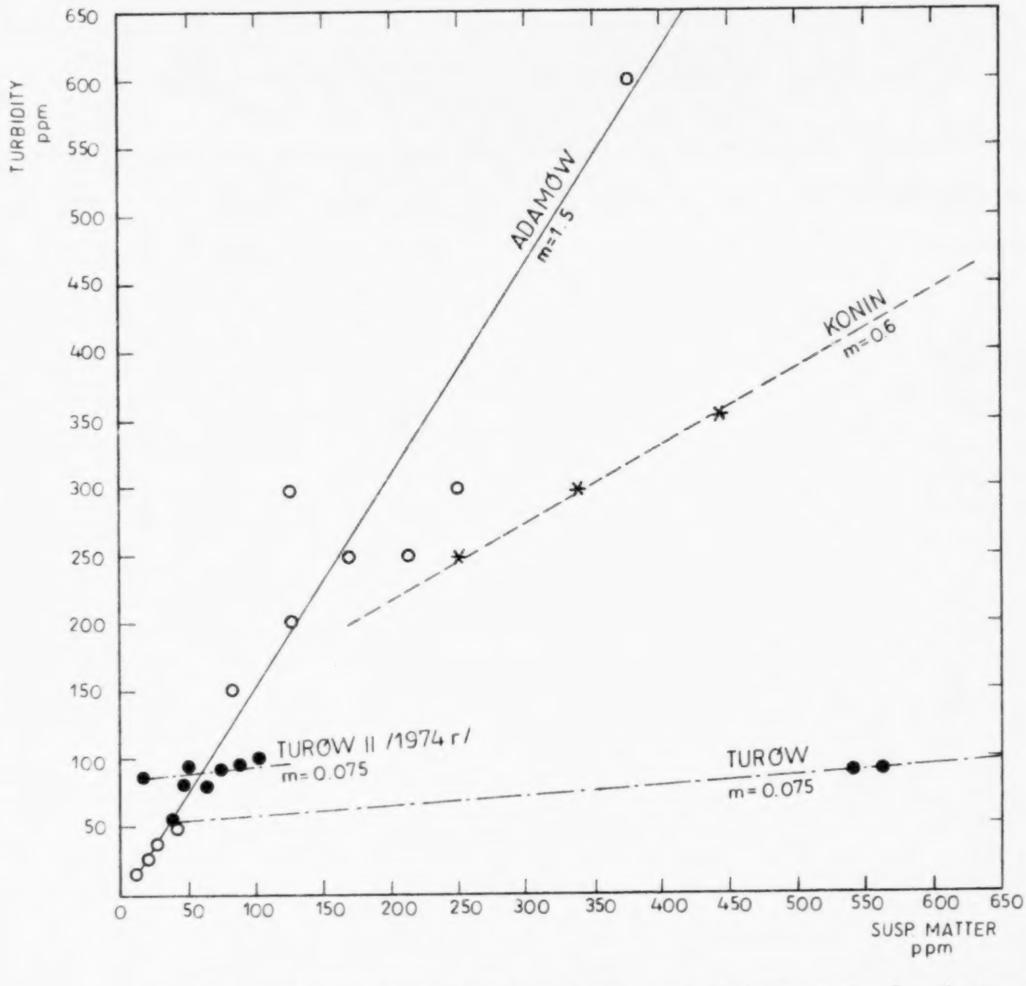
Observed results of the flocculation tests under laboratory conditions are shown in Table 13.

TABLE 10. PHYSICO-CHEMICAL COMPOSITION OF MINE WATERS KONIN-PATNÓW PIT

Parameter	Units	Test 5 4/21/75	Test 6 6/9/75	Test 9 7/28/75
Turbidity	ppm	250	360	300
Color	ppm	20	20	15
Smell		Veg 1	Veg 2	Veg 2
Reaction	pH	7.6	7.7	7.7
Basicity	mval/dm^3	6.4	4.2	6.5
Hardness	degree	17.8	16.8	18.8
Calcium	ppm Ca	89.2	93.5	74.5
Magnesium	ppm Mg	22.7	15.8	36
Chlorides	ppm Cl	16	32	17
Manganese	ppm Mn	n.t.	n.t.	trace
Total iron	ppm Fe	n.t.	n.t.	2.3
Ammonia	ppm N	0.1	n.t.	0.06
Nitrites	ppm N	0.005	0.005	0.06
Nitrates	ppm N	trace	trace	0.0
Oxygen demand	ppm O_2	22.0	14.6	16
Sulfates	ppm SO_4	48	94	102
Dissolved solids	ppm	413	523	482
Mineral	ppm	337	430	411
Volatile	ppm	76	93	71
Suspensions	ppm	250	472	335
Mineral	ppm	190	399	260
Volatile	ppm	60	73	75
Carbotane hardness	degree	17.8	11.7	18.2
Noncarbonate	degree	0.0	5.1	0.6
Temp. of water sampling	°K	286.0		
Potential	µVolt	-23	-18.5	-

TABLE 11. PHYSICO-CHEMICAL COMPOSITION OF MINE WATERS ADAMÓW

Parameter	Unit	Test 3 3/17/75	Test 4 4/7/75	Test 7 6/23/75	Test 10 7/25/75
Turbidity	ppm	300	600	250	300
Color	ppm Pt.	20	10	25	20
Smell		Veg 1	Veg 1	Veg 1	Veg 2
Reaction	pH	8.0	8.0	7.8	8.2
Basicity	mval/dm^3	4.2	4.1	3.6	4.5
Hardness	degree	19.0	19.3	17.0	20.2
Calcium	ppm Ca	107.0	108.0	94	110
Magnesium	ppm Mg	17.0	21.4	16	21
Chlorides	ppm Cl	34.0	26	32	30
Manganese	ppm Mn	0.28	n.t.	n.t.	
Total iron	ppm Fe	3.7	2.0	6.0	8.1
Ammonia	ppm N	n.o.	0.1	0.1	0.1
Nitrites	ppm N	0.001	0.007	0.001	0.005
Nitrates	ppm N	0.2	trace	trace	trace
Oxygen demand	ppm O_2	13.2	14.0	25	80
Sulfates	ppm SO_4	139	140	138	140
Dissolved solids	ppm	500	509	550	536
Mineral	ppm	415	395	439	
Volatile	ppm	85	114	111	
Suspensions	ppm	124	356	218	250
Mineral	ppm	97	308	196	
Volatile	ppm	27	48	22	
Carbonate hardness	degree	11.8	11.5	10.0	12.6
Noncarbonate	degree	7.2	7.8	7.0	6.9
Temp. of water sampling	^{o}K	280.0	280.0		
Potential	µVolt	-12.5	-18.0	-15.0	-16.0



NOTICE: For water from Turów II the scope of obcissae and of ordinates is ten times greater.

Fig. 2. Relation between turbidity and quantity of suspension (for laboratory tests).

TABLE 12. RELATIONSHIP BETWEEN TURBIDITY AND SUSPENDED SOLIDS

Type of Water	Suspended Solids ppm	Turbidity ppm	Remarks
Turów II	6313	1000	According to analyses of raw water after 2 hours of sedimentation.
	5795	1000	
	437	600	
	1070	1000	Raw water 1974
	882	1000	14
	890	1000	
	170	800	
	486	1000	
	708	900	
	571	800	
	537	900	
	502	700	
	204	220	
Konin-Patnów	250	250	
	472	360	
	335	300	
Adamów	124	300	
	356	600	
	218	250	
	250	300	
	13	10^x	
	17	20^x	
	25	30^x	
	35	50^x	
	86	150^x	
	130	200^x	
	172	250^x	

x - Results acquired from tests of water artificially made turbid with suspensions from sediment of mine water from Adamów.

TABLE 13. RESULTS OF THE LABORATORY FLOCCULANT TESTS

Ord. No.	Type of Polymer	Optimal Dose ppm	Moment of Floc Formation	Size of Flocs	Type of Sediment	Remarks
1	M-502	0.5	By the end of fast and in the course of slow mixing	fine and average	Loose, uniformly distributed at the reactor bottom.	Flocs fast sedimented in first 10 mins. of sedimentation. Residual turbidity, 3-10 ppm.
2	M-503	0.5-5.0	In the course of fast and slow mixing	fine and average	Loose, uniformly distributed at the reactor bottom.	Flocs fast sedimented in first 10 mins. of sedimentation. Residual turbidity, 3-10 ppm.
3	M-550	1.0	At the beginning of fast mixing	average and large	Compacted into lumps.	Flocs settled down partially already during slow mixing. Residual turbidity 30-40 ppm.
4	M-570	1.0	In the course of fast mixing	large	Compacted into minute lumps.	Flocks sedimented already...during slow mix. Residual turbidity 30 ppm
5	M-580	0.1-1.0	In the course of fast mixing	large	Compacted into small and large.	Lumps of sediment sedimented during slow mixing. Residual turbidity 15-80 ppm.
6	M-590	1.0	In the course of fast mixing.	large	Glued into large lumps	Lumps of sediment sedimented during slow mix. Residual turbidity 25-80 ppm.
7	Wt-2570L	5-30	In the course of slow mixing.	average and large	Compacted into large lumps in the middle of reactor bottom.	Lumps were setting in initial phase of sedimentation. Residual turbidity 10-30 ppm.
8	Wt-2640	3-5	In the course of slow mixing.	large	Compacted into small lumps in the middle of reactor bottom.	Flocks were falling in the course of the first 10 mins. of sedimentation. Residual turbidity 30 ppm.
9	Poly-hall 295	0.3-0.5	At the beginning of fast mixing.	large	Compacted into large lumps.	Large lumps falling in the slow mix course, small lumps in initial phase of sedimentation. Residual turbidity 30 ppm.
10	Poly-hall 297	1.0	At the beginning of fast mixing	large	Compacted into average and and small lumps.	Sediment lumps quickly fell during first 10 mins. Residual turbidity 25 ppm.
11	Poly-hall 540	1.0	At the beginning of fast mixing	large	Compacted into average and large lumps.	Lumps sedimented partly during slow mix time. Residual turbidity 25 ppm
12	Poly-hall 650	1.0-5.0	At the beginning of fast mixing	large	Compacted into large lumps or one spongy mass.	Lumps sedimented during slow mix. Observed difficult to sediment flocs Residual turbidity 15-60 ppm.
13	Poly-ox	0.1-0.5	By the end of fast and in the course of slow mixing.	small and average	Fine, compacted into lumps	Flocks were falling slowly, during the whole sedimentation period. Difficult to sediment flocs observed Residual turbidity 30-50 ppm.
14	Rokrysol WF-1	1-30	At the beginning of fast mixing (rapidly)	large, spongy	Compacted into large lumps and spongy agglomerations	Flocs sedimented during slow mix time. Residual turbidity 20-40 ppm.
15	Rokrysol WF-2	0.1-2.0 60	In the course of fast mixing	average and large	Compacted into small lumps.	Flocs sedimented slowly. Not sedimenting flocs in time of 20 mins. appeared. Residual turbidity 25-50 ppm.
16	Rokrysol WF-3	5.0 20-60	By the end of fast and in the course of slow mixing	small and average	Fine compacted into small lumps.	Flocs sedimented during whole sedimentation period. Residual turbidity 20-30 ppm.
17	Rokrysol WF-3	20.0	By the end of fast and in the course of slow mixing.	average and large	In shape of thick, strong flocs.	Flocs sedimented well in the first half of sedimentation period. Residual turbidity 10-15 ppm.
18	Gig-tar 3	10.0	In the course of fast mixing.	large	Fine, compacted into lumps.	Flocs sedimented already during slow mix. Residual turbidity 50-80 ppm.

RESULTS OF LABORATORY INVESTIGATIONS

Turow II Mine

Waters from the Turow II mine were subjected to investigations three times with the application of various types of flocculants in different doses, with varied pH and temperature. Results of these tests are presented in the Appendix. Turow II waters in comparison to waters from the Konin and Adamow mines were more difficult to purify.

In the first series of tests, the best flocculants from the point of view of turbidity and oxygen demand reduction were Calgon M-502 and M-503. Reduction in turbidity with a flocculant dose of 1 ppm approached 99%. Maximum reduction in oxygen demand (77-82%) was obtained with a dose of 10 ppm.

In the second series of tests the mine water was also strongly polluted with suspended particles. Only a few flocculants effected the flocculation process. Flocculants of polish production were not effective on this water. The best flocculant was Calgon M-502 in doses of about 5-10 ppm. A reduction in turbidity of about 97%, and of oxygen demand of 54% was obtained.

In the third series of tests the majority of flocculants studied, both of Polish and American production, did not give satisfactory results. Again Calgon M-502 was shown to be most effective and reduced the turbidity by about 96% and oxygen demand by 85%, but only with a dose of 30 ppm. In summary, the above tests showed that the optimal flocculant for the Turow mine waters was Calgon M-502 in doses of 1-30 ppm.

Water, which is characterized with a high proportion of its particles in the colloidal sizes, required higher flocculant doses. In cases when removal of suspensions with the use of flocculation alone were unsatisfactory, lime was used. The use of lime with Turow water worked well. Optimum doses of lime were from 200 to 300 ppm of CaO. Decrease in the lime dose was possible through the addition of polyelectrolites, used as aiding substances. Satisfactory results were achieved in the application of 100 ppm of lime and 2 ppm of Polyox, or 100 ppm of lime and 5 ppm of Rokrysol WF-5. Calgon M-502 used separately was the most effective polyelectrolite, but with the addition of lime it was shown to be ineffective. Polyox alone in a 5 ppm dose reduced the turbidity down to 150 ppm. The same level of purification was obtained by raising the pH to about 10 with soda lye. The influence of pH and temperature on the flocculation process was determined. Doses of polyelectrolites were varied within the limits of 0.01 to 100 ppm, however, most often they were from 0.1 - 5.0 ppm. Polyelectrolites Calgon M-502, Polyox and Rokrysol WF-5 were used in tests to determine the influence of reaction and temperature on the effects of flocculation. The pH was varied by the addition of 0.1 N soda lye or 0.1 N of hydrochloric acid within a 5 to 11 pH range. The temperature of the water samples was varied through immersions into appropriate thermostable baths within the limits of 273.5 to 296 K for water from Turow, 275 to 296 K for Konin-Patnow water, and 276 to 296 K for Adamow water.

The best results of turbidity and oxygen demand removal were achieved at 296 K temperature, while the change in pH from 5 to 9 did not affect the process. Increase in pH over 9.0, decreased the rate of turbidity and oxygen demand removal at this temperature, while with low temperatures this process progressed better when water pH was raised. The influence of pH and temperature on electrokinetic potentials is shown in Figure 3. No clear influence of temperature on the potential values was observed. Within the pH limits 5.0 to 9.0, the zeta potential was almost constant, while with pH > 9.0 an increase was observed. Despite a rise in the zeta potential satisfactory results in suspension removal were ascertained.

Polyox and Rokrysol WF-5 were used in combination with a constant dose of lime in quantity of 100 ppm of CaO. The dose of Polyox and Rokrysol WF-5 was varied from 0.1 to 5.0 ppm, and the temperature of water within 278-298 K. The change of temperature did not affect the process.

During the period under study iron in the water was found in the quantities of 0.5-2.5 ppm. Filtration decreased this value by half. In the process of coagulation with polyelectrolites the quantity of iron was decreased by raising the polyelectrolite dose. Removal of iron to trace values was achieved in the process of combined dosing with lime and polyelectrolites to water (Rokrysol WF-5, Polyox). The pH was set at 9.0. Temperature within the range studied did not affect the rate of iron removal.

Konin - Patnow Open-pit Mine

The results of three tests carried out on the removal of suspended solids from the Konin-Patnow open-pit mine water are presented in the Appendix. The best results were achieved with Calgon M-502, M-503, and the Rokrysol WF-5. The range of optimum doses was 0.1 - 5 ppm of Calgon M-502, and about 10 ppm of Rokrysol WF-5. In some cases the residual turbidity amounted to about 10-15 ppm. In these cases with pH adjusted to about 10, and the application of 0.3 ppm Calgon M-502 the turbidity could be reduced to about 5 ppm. With a dose of 3 ppm of Calgon M-502 removal of turbidity was 85-98%, and of oxygen demand - 30-60%. For Calgon M-502 the reduction was 80-95% and 33-55%, and for Rokrysol WF-5 85% and 60% respectively for turbidity and oxygen demand.

With the water from Konin and the use of Calgon M-502 the temperature had no impact on the process nor on the zeta potential (Figure 3). The range of investigated temperatures was 275-296 K. Optimum dose of lime for the water from Konin was 250-300 ppm, and corresponded to a pH of greater than 11.5. Concentration of iron in the water during the investigation period was about 0.6 ppm, and after filtering 0.15 ppm. Among the polyelectrolites tested the Polyhall, Polyox, and Rokrysol WF-5 removed iron to trace amounts. The rate of iron removal increased with increased dose amounts.

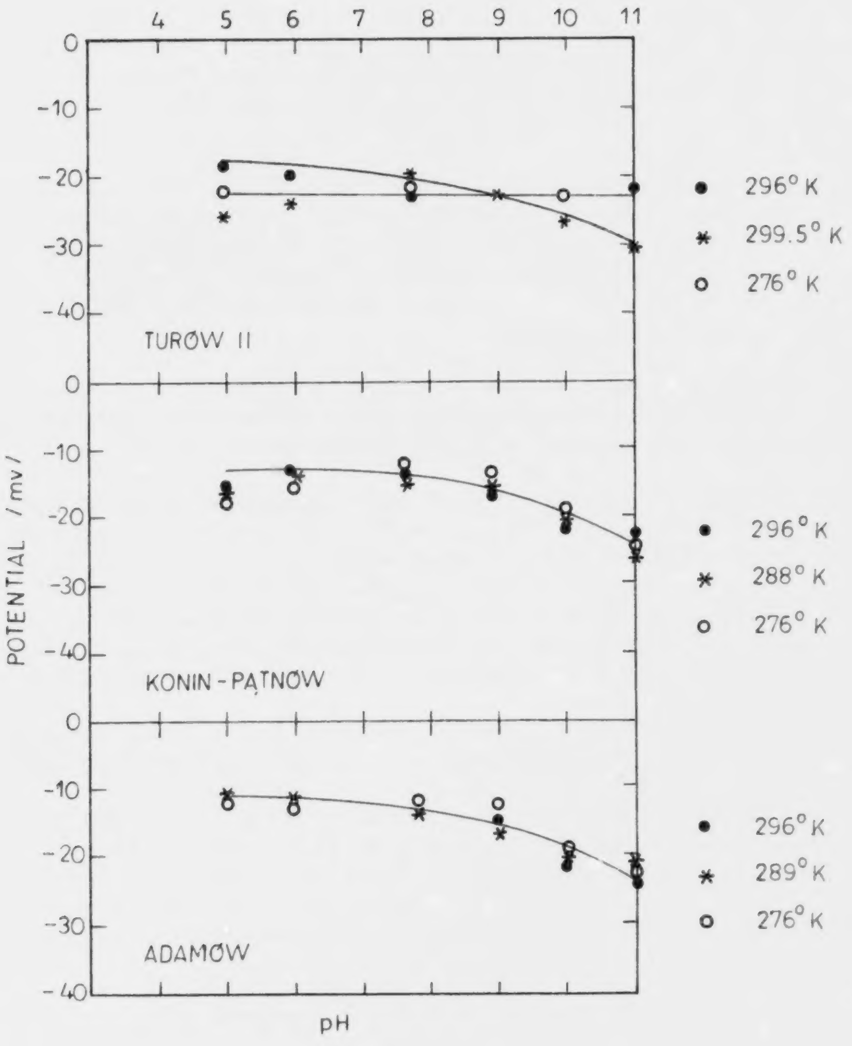


Fig. 3. Influence of pH and temperature on potential of particles.

Adamow - Open-pit Mine

Laboratory investigations of flocculants application for the purification of waters from the mine Adamow comprised 4 series (4 repetitions) of tests.

In the first test the most effective flocculant was Calgon M-502, which at a dose of 0.3 ppm produced a reduction in turbidity approaching 98% and in oxygen demand 40%. Increasing the dose to 0.5 ppm reduced the oxygen demand by 50%. Similar results were obtained in repetitions of the tests in this series.

From the polish flocculants the most effective was Rokrysol WF-5 which with doses of 2-20 ppm reduced turbidity 84-88%, and oxygen demand by 58-64%. With the application of Rokrysol at 3 ppm, in some cases no reduction in turbidity nor in oxygen demand was observed. The optimium doses for Calgon M-502 was from 0.5 to 5.0 ppm, as compared to Rokrysol WF-5 which was from 2 to 10 ppm.

No temperature influence within the range of 276-296 K on the effects of purification with the use of Calgon M-502 was ascertained. Increasing pH to more than 9 improved the removal effects of suspended solids.

Water sampled from Adamow in August 1975 contained large amounts of organic pollutants (COD - about 80 ppm of O_2). A very effective coagulant in this case was iron sulfate. Optimum dose amounted to 50 ppm of $Fe\ (SO_4)_3.9H_2O$. The turbidity was reduced to 10-15 ppm at the same time. A combined application of iron sulfate with Calgon M-502, or Polyox did not improve the removal of COD or turbidity. Improvements in purification were achieved with an application of iron sulfate and a pH adjusted to 8.2 prior to coagulation.

In coagulation with iron sulfate temperature had a small influence in removal of the oxygen demand. The best results were achieved at 292 K.

The Adamow water had the highest content of iron (5.7 - 8.9 ppm of Fe, after filtration - 0.8 - 1.5 ppm). As the doses of polyelectrolites was increased, the rate of iron removal also increased. Best results of iron removal were achieved using Polyhall, Rokrysol WF-5, or the iron sulfate together with Polyox. Calgon M-502 as an aid to coagulation with iron sulfate, did not improve treatment.

INVESTIGATION OF THE COAGULATION PROCESS, BASED ON ZETA POTENTIAL

Colloidal and suspended particles differed in their electrokinetic potential. The highest values of zeta potential were found in the mine waters from the open-pit Turow II (-23 to -45 v), lower values were found in waters from the open-pit Konin-Patnow (-18.5 to -23 v), and the lowest values from the Adamow open-pit waters (-12.5 to -18.0 v). According to the literature, the most difficult waters to purify are those containing stable colloidal particles with a low zeta potential. However these tests showed that the most difficult waters to purify were from the open-pit Turow II, and the easiest from the open-pit Adamow. In these tests it was found that the process of floc formation took place with zeta potentials close to the value of that in the raw water.

Changes in electrokinetic potential were dependent on the doses of the selected polyelectrolites (Figure 4). As shown in the Figure, the most effective polyelectrolite should have been Calgon M-502. This finding was confirmed in the conventional tests. The range of the zeta potential found during the flocculation studies fluctuated for water from Turow II from -17 to -23 v , for water from Konin-Patnow from -10.5 to -23 v , for Adamow from -8.5 to -20 v .

In some instances a rise in zeta potential relevant to the raw water values was observed after the addition of polyelectrolites. Despite this increase the floc formation process was taking place. Presumably in these cases the zeta potential was not determining the stability of the colloids. Moreover the same potential value for different polyelectrolites produced different purification results with the same water. With the pH raised to 10 to 11, an increase in the zeta potential was observed, to values of -27 from -30 v for Turow water, to -25 from -27 v for Konin water, and to about -24 v for water from Adamow. Satisfactory purification at these values of zeta potential, illustrate the effectiveness of chemical precipitation of suspensions. In the case where iron sulfate was applied to Adamow water, the floc formation appeared by zeta values from -12.5 to -19 v , and residual turbidity was 20 ppm. This turbidity decreased to under 5 ppm by raising the pH to 8.2. In coagulation with lime the Konin-Patnow waters, an effective turbidity removal took place at a zeta value of about -3 v .

The influence of temperature on the zeta potential in the process of coagulation is shown in tables in the Appendix. Selected tests are shown in Figure 3. From the diagrams it appears that in the process of coagulation with polyelectrolites, the temperature was not affecting the zeta potential. A small influence was observed when iron sulfate was used.

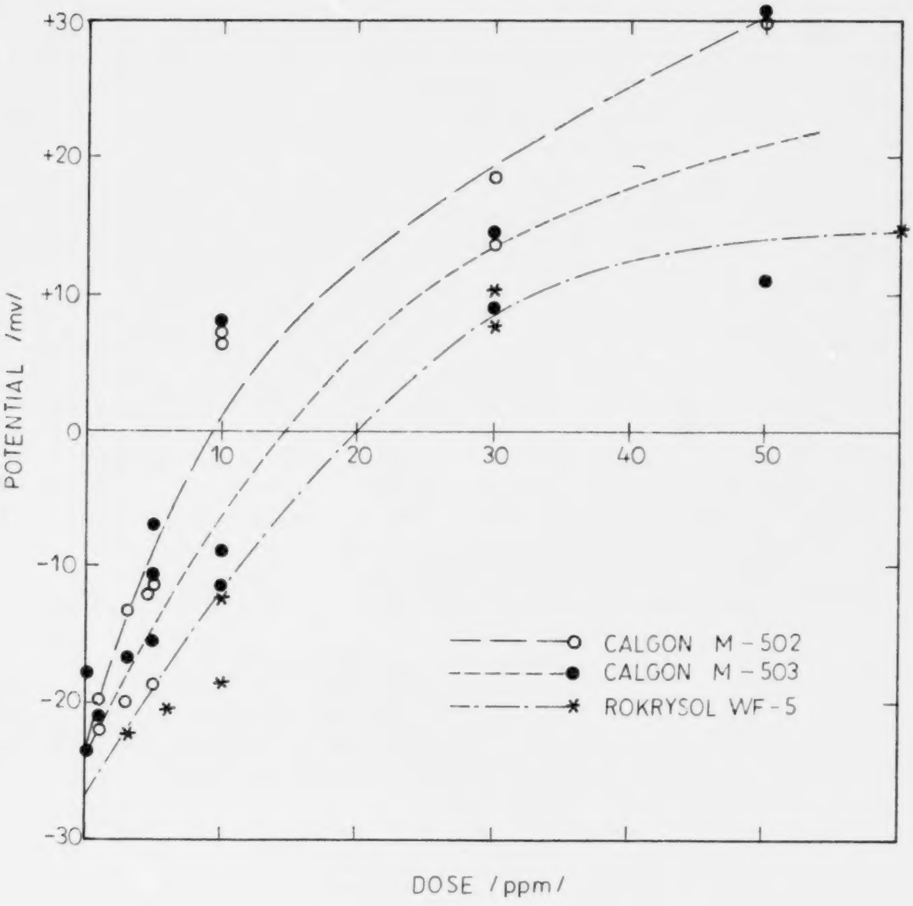


Fig. 4. Zeta potential as a function of Polyelectralite dose.

SECTION 7

LABORATORY STUDIES OF FACTORS INFLUENCING THE FLOCCULATION PROCESS

INFLUENCE OF THE CONCENTRATION OF THE DOSED FLOCCULANT

These investigations were carried out on waters from the Adamow mine having a turbidity of 40-50 NTU, and on waters from the open-pit mine Turow, with higher turbidity level of 350-400 NTU.

In the tests Calgon M-502 was used as the flocculant in concentrations from 0.025 to 2.0% at doses from 1 to 20 ppm. The tests were carried out in a six-stand flocculator under the following conditions:

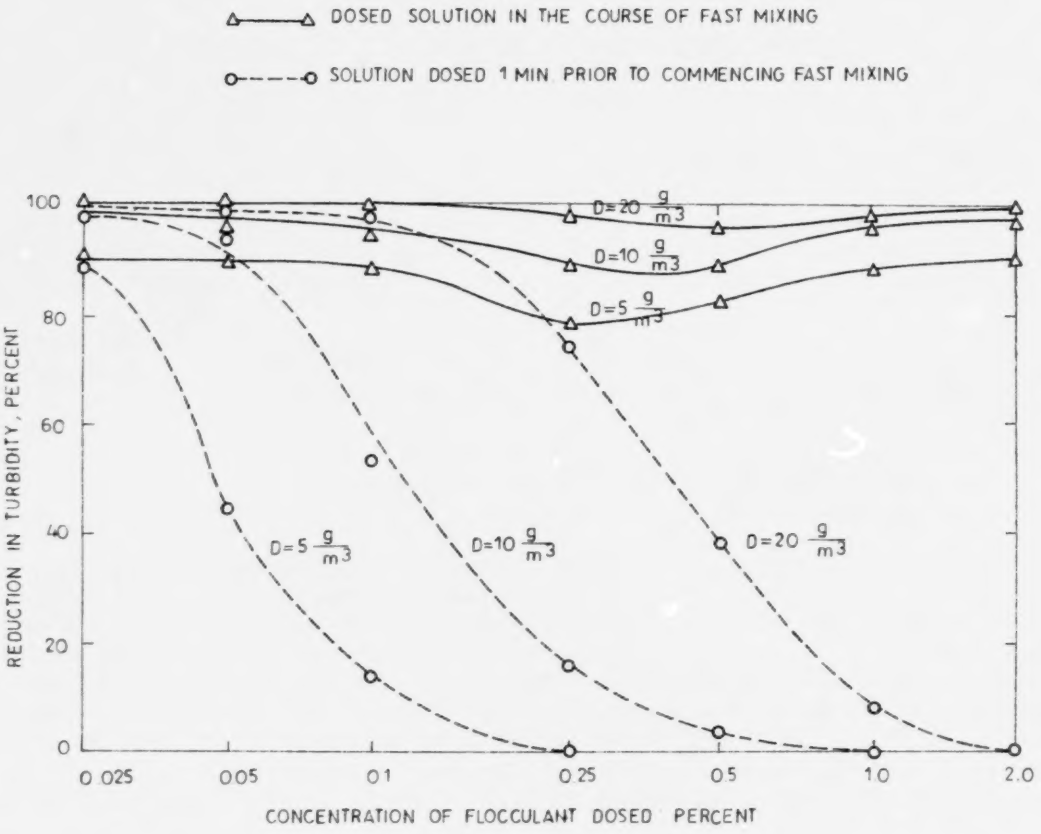
- fast mix, at 80 revs/min for 8 min.
- slow mix, at 20 revs/min for 20 min.
- sedimentation for 20 min.

The investigations revealed a relationship existed between concentration of the flocculant solution and purification performance. This relationship was more evident in waters with high turbidity, and the application of low or average doses of flocculant. It was found that for the Calgon M-502 optimal solution concentrations were within the range of 0.1 - 0.5%, and the best results were obtained at concentrations of 0.2 - 0.3%. Lower concentrations than 0.1% and higher than 0.5% had no visible influence on the purification process. The results of these investigations are presented graphically in the diagram, Figure 5, for waters from the mine Turow with doses of flocculant of 5-20 ppm.

Also presented in Figure 5 (dashed line) are results obtained when the flocculant was dosed one minute before fast mixing. As can be seen in the figure this had a clearly negative influence on the effects of purification.

INFLUENCE OF FAST MIXING

In the first phase of the laboratory tests to select the best type of flocculant, identical times of mixing were used, i.e., most often 2 minutes of fast mixing, 20 minutes of slow mixing and 20 minutes of sedimentation. After the selection of cationic flocculants as the most suitable ones an additional analyzing was made to determine the influence of other fast mixing time period. These tests were made on Adamow waters having a turbidity of 40 NTU and using a 0.1% solution of Calgon M-502 and doses of 0.1, 0.3, 0.5, and 1.0 ppm. The time of fast mixing (80 rev/min) was varied from 1-30 minutes.



PARAMETERS: 8' - FAST MIX. 80 REVS./MIN.
20' - SLOW MIX. 20 REVS/MIN
20 - SEDIMENTATION
WATER TURBIDITY 370 NTU
CALGON M-502

Fig. 5. Effect of dose concentration on coagulation.

Results of these tests are presented in Figure 6. The time of fast mixing had an influence on turbidity removal when a cationic flocculant was used. The optimum period of fast mixing, independent of the flocculant dose, was found to be 8-10 minutes. Longer periods did not have a marked influence.

APPLICATION OF AIR DURING FAST MIXING

The use of compressed air streams during fast mixing was investigated. Adamow water was used with the addition of Calgon M-502 in 5 and 10 ppm doses and mixing with air was applied for periods of 5-10 minutes, at different intensity of aeration. The tests were carried out with mechanical mixing and air addition, and of wholly mechanical mixing.

The results of these tests are presented in Table 14. The most optimum system was fast mixing with aeration for about 10 minutes and then mechanical mixing for about 3 minutes. This method of mixing produced a reduction in turbidity to 15 NTU, which was better than mechanical mixing alone for 10 minutes. When aeration was used very small floccs formed which were difficult to settle. Flotation of the particles occurred at a 10 ppm dose, but to a smaller degree.

TABLE 14. RESULTS OF TESTS WITH AERATION DURING FAST MIXING*

Dose of flocculant	ppm	5.0					10.0		
Aeration time	min.	5	5	-	-	10	5	5	5
Aeration intensity	1/h	200	500	-	-	50	50	200	500
Time of fast mix 80 rev/min	min.	-	-	5	10	3	-	-	-
Sedimentation time	min.	30	30	30	30	30	30	30	30
Turbidity, final	NTU	40	30	80	25	15	40	40	40

*Turbidity of raw water - 300 NTU, Calgon M-502 used.

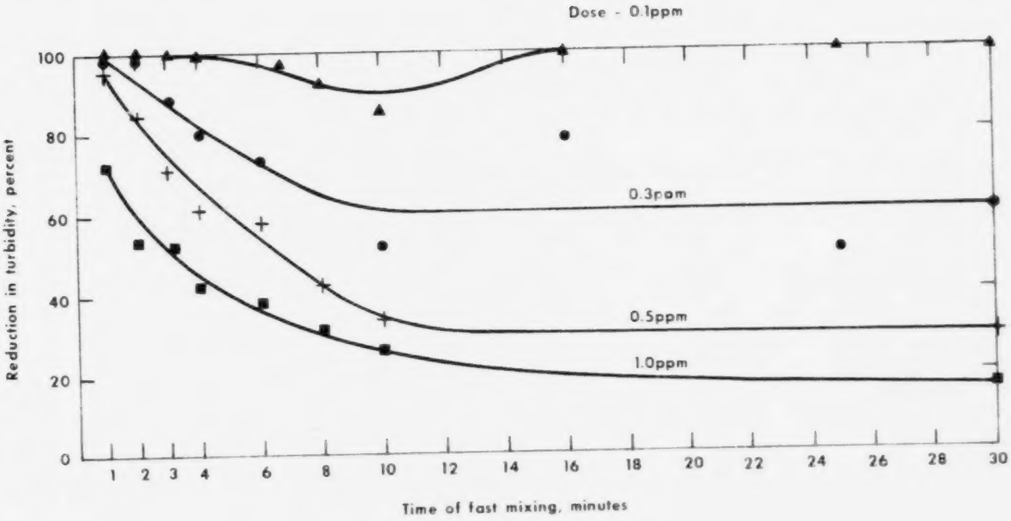


Figure 6. Effect of length of fast mixing on turbidity removal

SECTION 8

FIELD INVESTIGATIONS

Field investigations constituted the second phase of research work and were carried out in 1976 and 1977 in a specially constructed experimental sedimentation basin at the lignite mine Adamow. The objective of this phase of research was the determination of the hydraulic parameters of an experimental sedimentation basin, and the determination of the effectiveness of purification with the application of flocculants (Calgon M-502, and Rokrysol WF-5) which were found best in laboratory studies under field conditions.

DESCRIPTION OF THE RESEARCH SEDIMENTATION BASIN

The experimental sedimentation basin was situated close to the sedimentation basin purifying waters discharged from the open-pit mine Adamow. Waters delivered to the experimental sedimentation basin were diverted from an open channel carrying polluted waters pumped from the open-pit mine. The sedimentation basin had dimensions at the bottom of 7 x 60 m, slope gradient 1:2 and a 2.5 m depth. By proper arrangement of the receiving water flumes the basin could be operated at depths of 1.2 and 2.2 m. An entrance and sedimentation chamber were allotted in the sedimentation basin. The water entered and exited from the sedimentation chamber across the whole width of the basin. Adjacent to the inlet of the sedimentation basin an arrangement for dosing and mixing of flocculants was constructed.

The equipment to prepare and to dose the flocculants were located in a small building. Solutions of flocculants were dosed with a piston pump into a mixing chamber into which polluted water flowed. After gravitational mixing, with the flocculant, the water was delivered by an open ditch to the sedimentation basin, or to a chamber where further mixing occurred with the use of compressed air. The ditch, in which the water was carried to the sedimentation basin was equipped with partitions that lowered the water in steps, which provided further mixing. From here the water flowed into the entrance chamber where the natural conditions of slow mixing existed. The water then overflowed into the sedimentation chamber.

The sedimentation basin was equipped in a manner that the flow could be varied over a wide range. A sampler that collected samples at predetermined time intervals was used. In addition the direction and velocity of the wind was measured. The bottom and slopes of the sedimentation basin were lined with a layer of insulating foil preventing infiltration of the water into the soil. Total capacity of the sedimentation basin at the 1.2 meter depth was 670 m^3, and at 2.20 m depth it was 1536 m^3.

Sedimentation basin also was equipped with 3 platforms enabling water sampling to be collected across the basin at these different locations. Construction of the sedimentation basin together with details of its inlets and outlets is shown in Figure 7.

HYDRAULIC TESTS OF THE SEDIMENTATION BASIN

Preliminary Information

The experimental sedimentation basin was submitted first to hydraulic tests. The application of instrument to measure and investigate flow hydraulics is limited owing to the occurrences of very small flow velocities. In such conditions the best method of investigation is by means of tracers. They allow the collection of information regarding the conditions of flow and the hydraulic efficiency of a sedimentation basin. Tracer methods present the ability to determine the so called curve of flow (flow wave). The curve of flow is determined by the changes in tracer concentration, introduced at the inlet, in the water flowing out of the sedimentation basin. A graphic picture of the statistical distribution of residence time of particular particles of marked water in the sedimentation basin is obtained. On the basis of an analysis of this diagram the basic parameters of flow in the sedimentation basin are computed, which define the so called "sedimentation basin stability."

Stability determines, in general, to what extent the true time of flow of all particles of water entering the sedimentation basin is in relationship to the theoretical time calculated from the formula:

$$T_T = \frac{V}{Q}$$

where: V = sedimentation basin's capacity (m^3)
Q = inflow rate (m^3/sec)

Only an ideal sedimentation basin has 100% stability. In a real sedimentation basin water particles outflow at different times. Part of the water will reach the outlet in a time shorter than theoretical, while part will stay longer than would appear from the theoretical time of flow. The reasons can be:

- different velocities of flow across the sedimentation basin's cross-section
- occurrence of short circuits or areas in the basin where conditions exist of greater flow velocities
- existence of dead spaces
- disturbances of flow caused by the wind, different density of inflowing water, thermic changes or changes in suspension concentration.

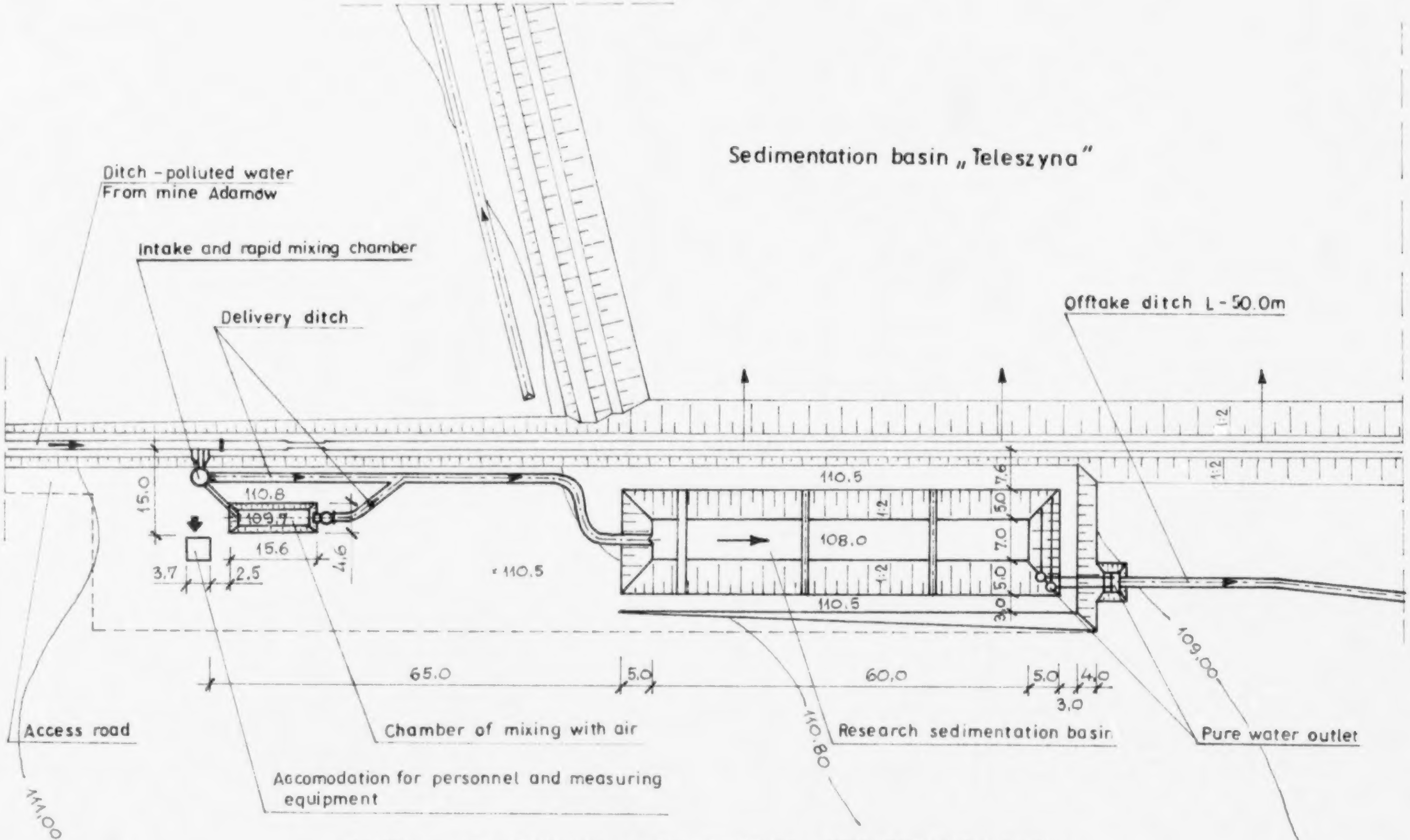

Sedimentation basin „Teleszyna"
Ditch - polluted water
From mine Adamow
Intake and rapid mixing chamber
Delivery ditch
Offtake ditch L - 50.0m
1:2
1:2
110.8
109.7
15.0
15.6
4.6
3.7
2.5
110.5
110.5
108.0
110.5
1:2
1:2
7.6
5.0
7.0
5.0
3.0
65.0
5.0
60.0
5.0
4.0
3.0
109.00
110.80
111.00
Access road
Chamber of mixing with air
Research sedimentation basin
Pure water outlet
Accomodation for personnel and measuring equipment

FIGURE 7. POSITIONING OF THE TESTING SEDIMENTATION BASIN

0 5 10 20 30 40 50m

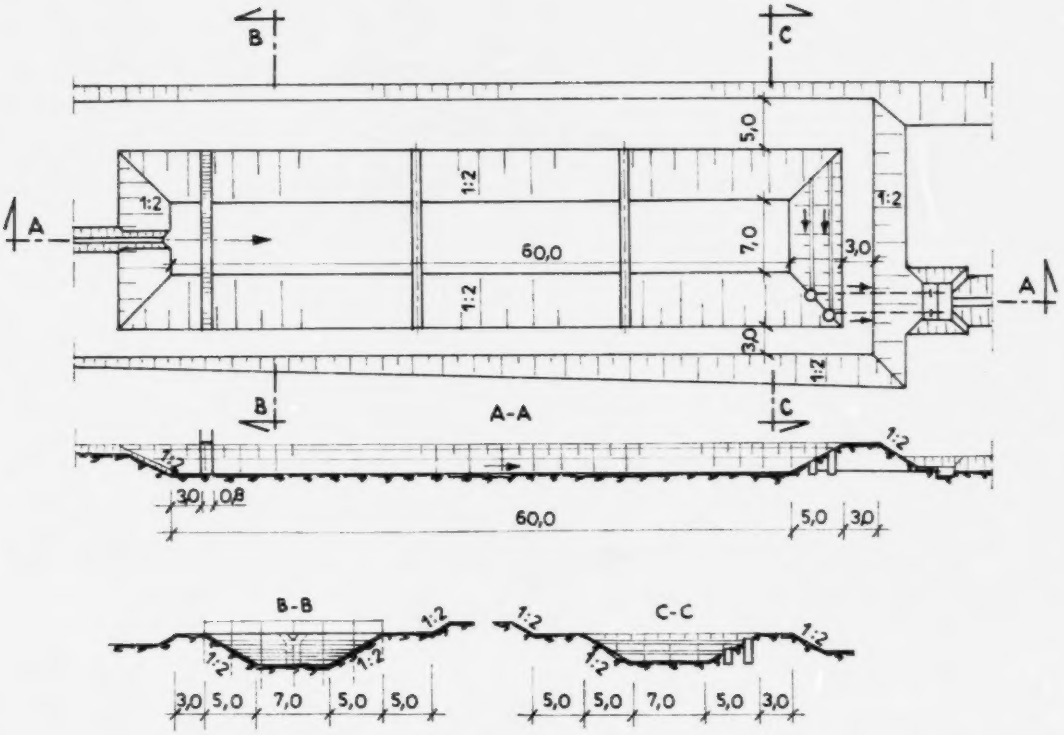

B
C
A
A
5,0
1:2
1:2
7,0
60,0
3,0
1:2
1:2
3,0
1:2
B
C
A-A
1:2
1:2
3,0
0,8
60,0
5,0
3,0
B-B
1:2
1:2
1:2
3,0
5,0
7,0
5,0
5,0
C-C
1:2
1:2
1:2
5,0
5,0
7,0
5,0
3,0

FIG.8 CHAMBERS OF THE EXPERIMENTAL BASIN

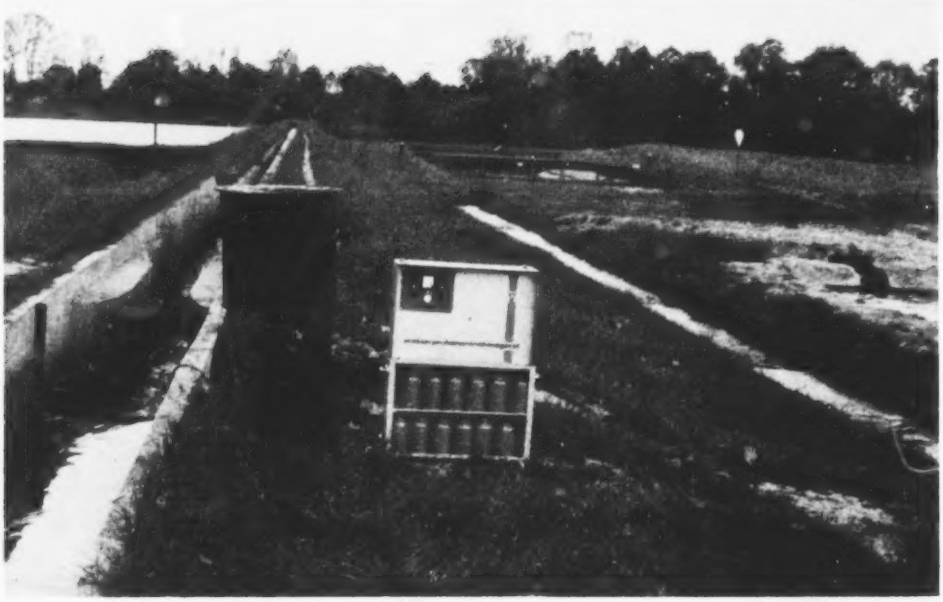


Figure 9. View of Ditch Carrying Mine Water, Sampler and Basin

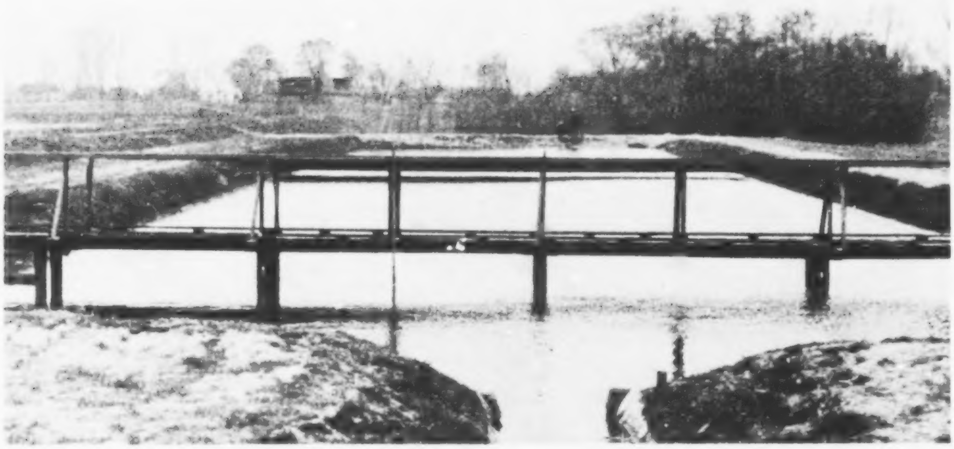


Figure 10. Experimental Sedimentation Basin at Maximum Depth

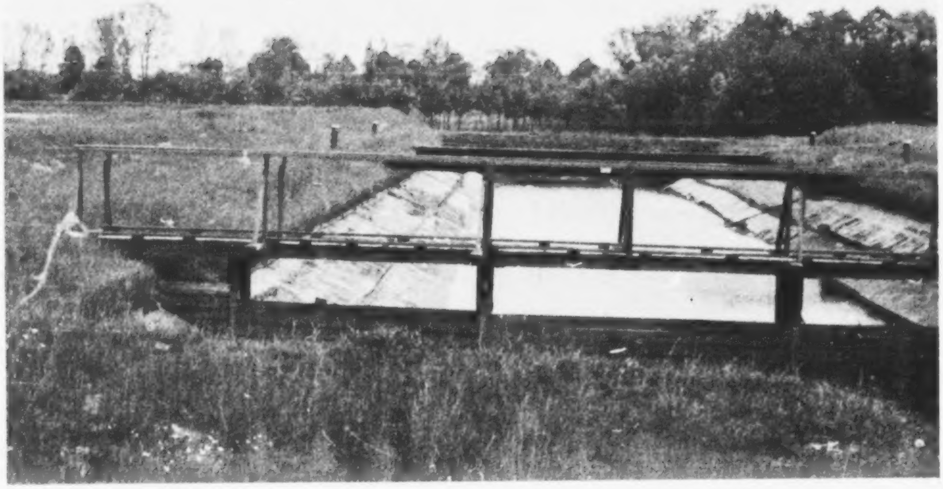


Figure 11. Experimental Sedimentation Basin Empty After Completion of Tests from Inlet End

Figure 12. Building with Field Laboratory, and Flocculant Mixing and Pumping Equipment

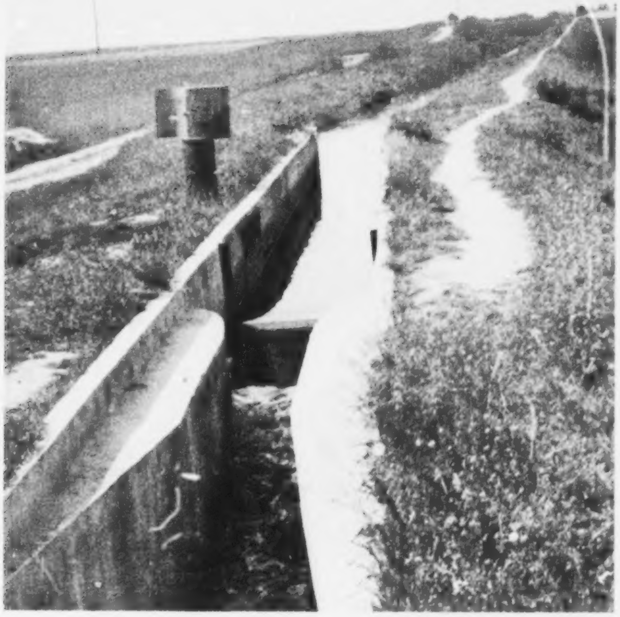


Figure 13. Water Intake to the Experimental Sedimentation Basin from Ditch Carrying Mine Water

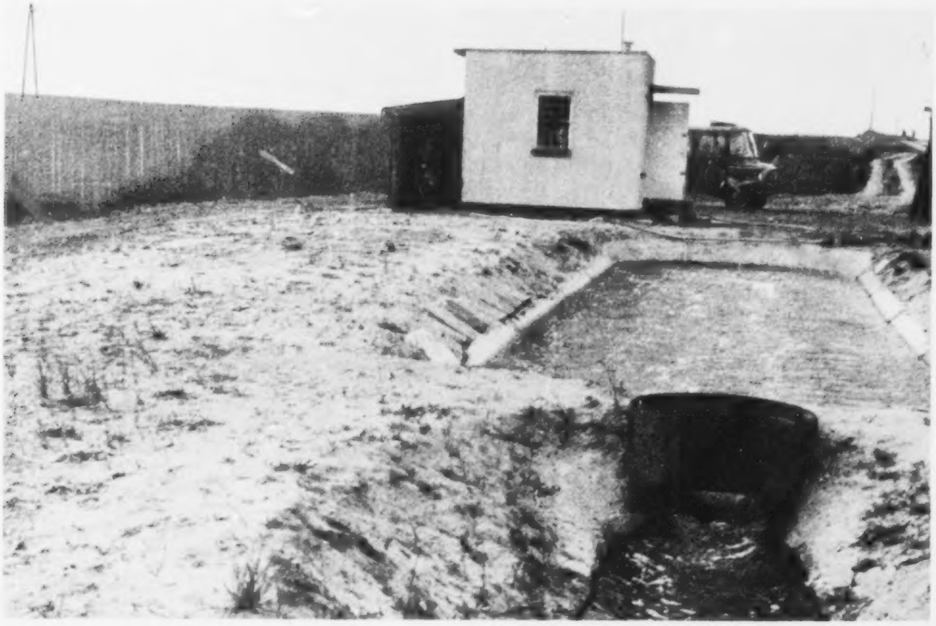


Figure 14. Chamber for Rapid Mixing with Air - View from the Side of Outlet

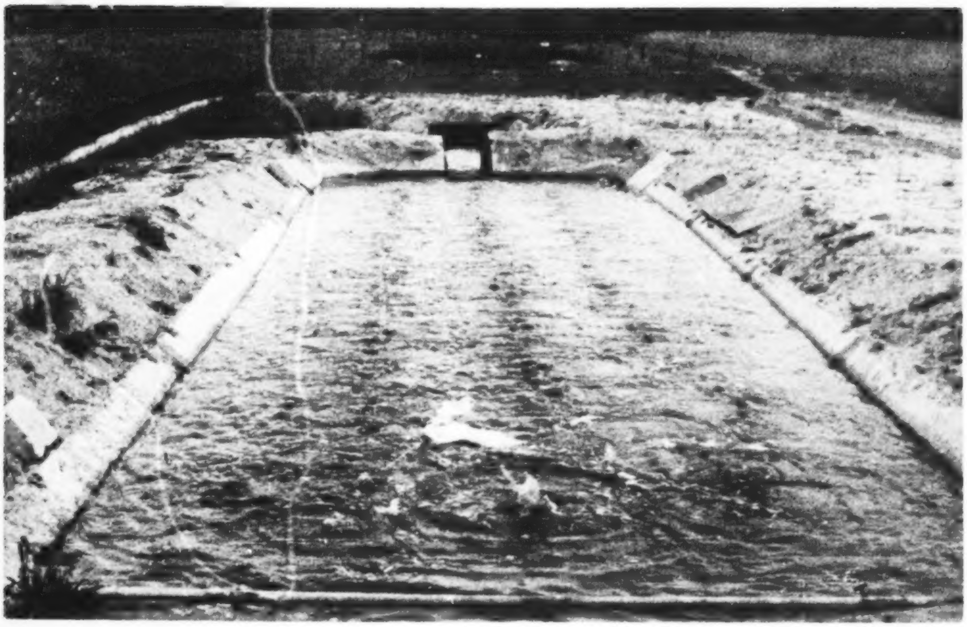


Figure 15. Rapid Mixing Chamber with Compressed Air

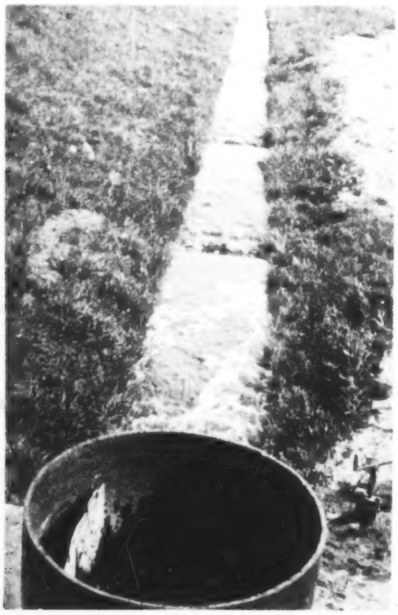


Figure 16. Rapid Mixing Well and Ditch with Barriers for Gravitational Fast Mixing

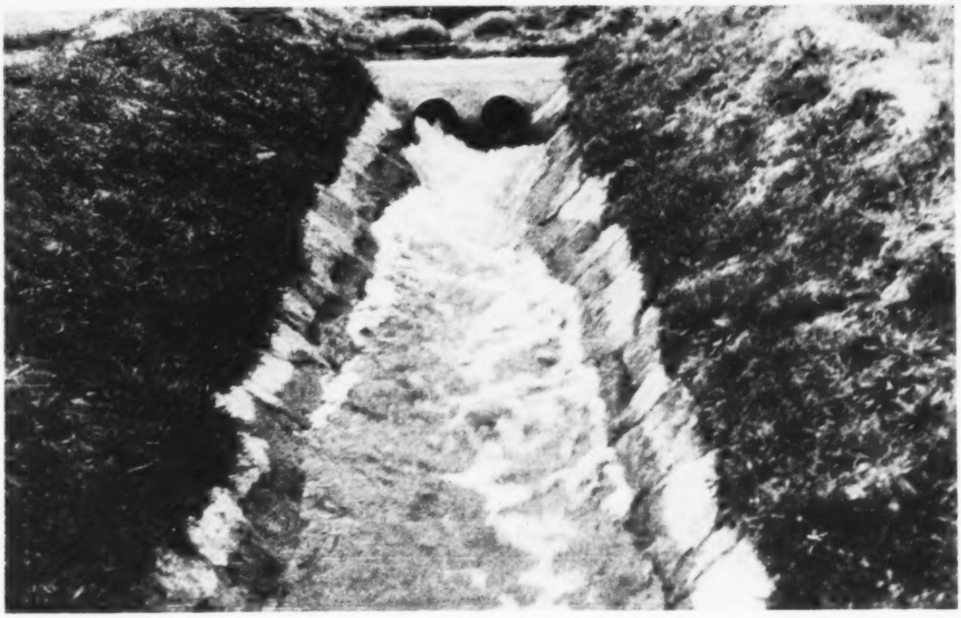


Figure 17. Outlet from Rapid Mixing Well

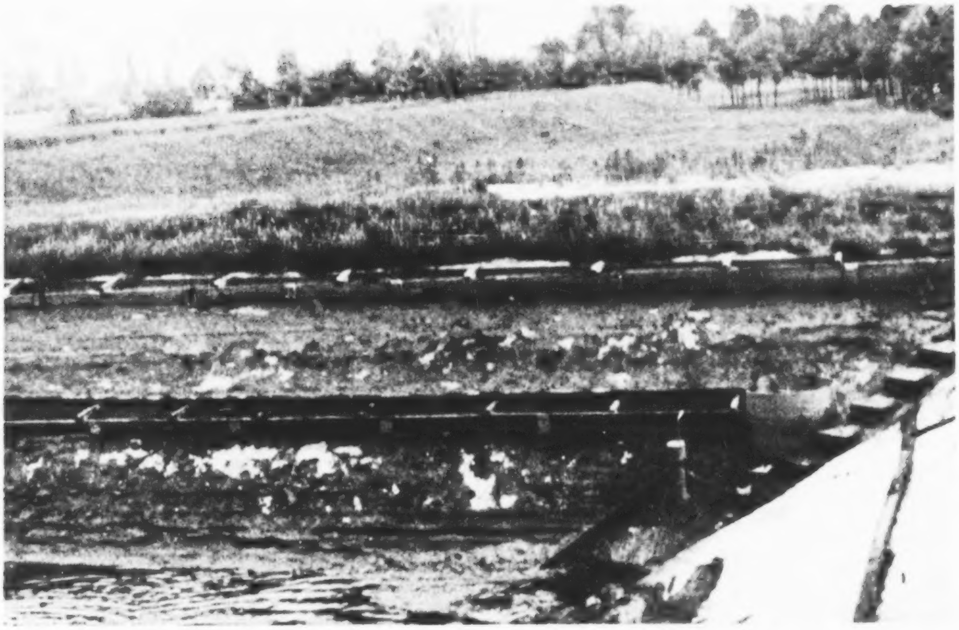


Figure 18. Effluent Trough of Sedimentation Basin

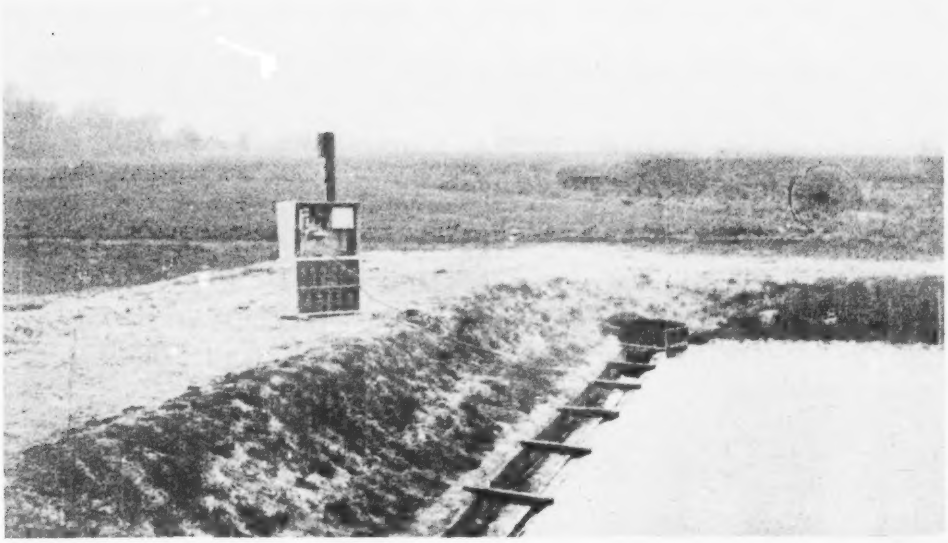


Figure 19. Effluent Trough at Maximum Depth and Sampler

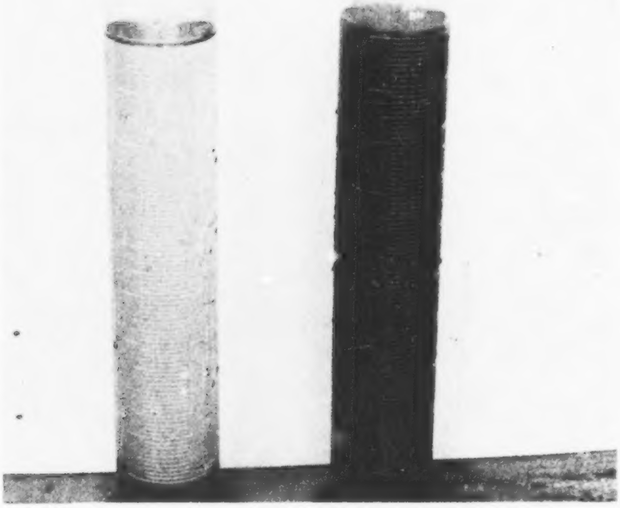


Figure 20. Effect of Sedimentation Basin Work with the Application of Calgon M-502

For a mathematical comprehension of the flow through a real sedimentation basin, simplified models of flow can be employed. There are four basic models of flow:

a. piston flow
b. perfect mixed flow (complete mixture)
c. flow with small longitudinal mixing
d. flow with mixture and dead spaces.

Of greatest practical significance are models for perfect mixture and those which are a combination of piston flow and perfect mixture. Models of piston flow have no practical use, as such flows in Newtonian fluids do not occur.

In this research it was assumed that in a sedimentation basin the flow is a combination piston and perfect mixture flow and that in the total volume of sedimentation basin there is certain volume composing dead space taking no part of the flow.

Tracers in Hydraulic Tests of Flow in Sedimentation Basins

Tracers are the substances deliberately introduced to the water at an inlet to sedimentation basin, and whose concentration is measured at the outlet in order to evaluate the performance of the basin. They have to fulfill a number of conditions. First of all, they should behave similarly to the particles within the fluid being investigated and not affect the hydrodynamic conditions of the flow. Moreover they should not fade away as a result of chemical reactions, action of light, volatilization or sorption. They should be easily soluble, detectable in low concentrations by simple analytical methods, and safe to use. In addition they must not appear in large concentrations in fluid being investigated because excessive concentration could hinder the collection of accurate results.

For this study isotopes and fluorescein were utilized. Suitably prepared tracers were injected into the well near the inlet, and their concentration was measured on the outlet of the sedimentation basin. The isotope concentration was measured with a waterproof counter probe of Geiger-Muller type and presented in diagram form showing impulses number as a function of time. Isotope test was made under various flow conditions, thus different theoretical times of retention. Measurements were made at two different water levels in the sedimentation basin. Regulation of water inflow was made through changes in the water levels in the open ditch at the intake and corresponding closings of pipelines by the inlet well.

Prior to the isotope studies a series of tests were performed to determine the volume of flow at 4 characteristic closings of the intaking pipelines with different inflows from the ditch delivering polluted waters from the open-pit mine Adamow. The depth of water in the ditch was regulated with help of log stops placed in special recesses in a concrete flume within the ditch.

Selected for hydraulic tests were inflows which gave theoretical retention times in the sedimentation basin of 1.6 to about 30 hours. During the test runs the speed and direction of wind and the temperature of water and air were measured.

The results of the tests are in time-concentration flow wave diagrams (see Figures 27-33 Appendix).

Interpretation of the results of the hydraulic characterization studies were oriented mainly on:

1. The determination of real time of flow corresponding to average time of water retention in the sedimentation basin.

2. The determination of the hydraulic efficiency of the sedimentation basin which was expressed as a ratio of average time of retention (T) to the theoretical time (T_T).

   $$\eta = \frac{T}{T_T}$$

   with the ratio of median time to theoretical time;

   $$\eta = \frac{T_{50}}{T_T}$$

   with the ratio of so called standard time of flow

   $$t_s = \frac{T_M + T_{50}}{2} \quad \text{to theoretical time} \quad \eta_2 = \frac{t_s}{T_T}$$

3. The determination of piston flow (p) and of perfect mixture flow (1-p) in sedimentation basin.

4. The determination of the proportion of dead space (m) and of active capacity (1-m) relationship to the total volume of the sedimentation basin.

Interpretation of the results was made by two methods: a classical method based on utilization of the T_{50} and T_M of the wave curve and a method described by Wolf and Resnick[31]. This latter method enables the determination of the hydraulic characteristics of the sedimentation basin in a relatively simple way, utilizing for this purpose a full range of the flow curve. In this method the flow curve is approximated by the equation:

$$F\left(\frac{T_n}{T_T}\right) = 1 - \exp\left[\alpha\left(\frac{T_n}{T_T} - \beta\right)\right]$$

where:

$F\left(\frac{T_n}{T_T}\right)$ - is a function expressing the tracer quantity which leaves the sedimentation basin in time (relative) $\frac{t_n}{T_T}$

$\alpha\beta$ - coefficients characterizing hydraulic parameters of flow, value of piston flow, of perfect mixture and of dead spaces.

t_n - real time of flow measured from the time of injecting the tracer.

T_T - theoretical time of flow.

Values of α and β for various types of flow occurring in sedimentation basin will adopt the following characteristic values:

- piston flow $\alpha \to \backsim$, $\beta > 0$
- perfect mixture flow $\alpha \overset{-}{>} 1$, $\beta = 0$
- occurrence of hydraulic breakthrough $\alpha < 1$, $\beta < 0$.

According to the method of Wolf-Resnick the participation of zones of flow, of mixture and stagnation in the sedimentation basin volume may be determined employing the following formula

$$\alpha = \frac{1}{(1-p)(1-m)}$$

$$\beta = p\ (1-m)$$

After inserting these values into basic equation and obtaining logarithms of both sides we acquire the following expression:

$$\lg\ \left[\ 1 - F\left(\frac{t_n}{T_T}\right)\ \right] = \frac{-\ \lg e}{(1-m)(1-p)}\ \left[\ \frac{t_n}{T_T} - p\ (1-m)\ \right]$$

The diagram of this equation on a semilogarithmic scale is a straight line, the inclination of which determines the value of the α coefficient:

$$\frac{\lg e}{(1-m)(1-p)} = \alpha\ \lg e$$

while the intersection of the abscissae axis by $F\left(\frac{t_n}{T_T}\right) = 0$

gives the relative time of the tracer appearance in the outflow corresponding to the value of the β coefficient:

$$\beta = p\ (1-m)$$

Therefore having values of the α and β coefficients we can calculate the characteristic parameters of flow, solving two equations with two unknowns:

$$p = \frac{\alpha\beta}{1 + \alpha\beta}$$

$$m = 1 - \frac{1 + \alpha\beta}{\alpha}$$

Hydraulic efficiency expressing the rate of effective utilization of the sedimentation basin's capacity can be defined as a ratio of active capacity to the total capacity of the sedimentation basin. Hence the value of hydraulic efficiency corresponds to a 1-m value. Real average time of flow through the sedimentation basin can therefore be computed from the following formula:

$$1 - m = \frac{T}{T_T}$$

The value of average real time of flow through a T sedimentation basin can also be determined in another way. This value is the gravity center of an area demarcated with the flow curve and the value of tracer's natural background. This can therefore be computed as the moment of time of the first rank and determined from the formula:

$$T = \frac{\int_0^{\infty} t \cdot C(t)\,dt}{\int_0^{\infty} \cdot C(t)\,dt}$$

In case when the shape of obtained curve is symmetric, average real time of water residence in the sedimentation basin is equal to the median and the average standard time of flow

$$T = T_{50} = ts$$

Computation of the T value is then very easy. Having measured values $\frac{Cu}{C} = F\left(\frac{t}{T_T}\right)$ and the corresponding $\frac{T}{T_T}$ values and presented them on a semi-logarithmic system lg (1-x), the graphs of the flow waves are in a form of a straight line approximating values acquired from investigations. Approximation was achieved with the method of least squares.

All computations were made with the computer Odra 1306 according to a special program JAMI elaborated in Poltegor. Results of carried out computations are specified in Table 15.

TABLE 15. RESULTS ACQUIRED FROM ANALYSIS OF THE FLOW WAVES

Used tracer	Water inflow quantity Q	Depth of sedimentation basin	Capacity of sedimentation basin	Theoretical time of retention T_T	Average real time of retention $t_n = T$	Median time T_{50}	Mode time T_M	Standard retention time $\frac{T_{50} + T_M}{2}$	Piston flow	Perfect mixture flow	Dead spaces	Active sedimentation basin volume 1-m	Standard active basin's volume $\frac{\frac{T_{50} + T_M}{2}}{T_T}$	Usual active basin's volume $\frac{T_{50}}{T_T}$
	m^3/mns.	m	m^3	mns.	mns.	mns.	mns.	mns.	%	%	%	%	%	%
I	6.90	1.20	670	97	72.7	60.1	45	52.5	48	52	25	75	54	62
I	0.82	1.20	670	817	588.2	403.2	132	267.6	13	87	28	72	33	49
I	1.54	1.20	670	435	378.5	324.5	245	284.8	53	47	13	87	65	75
I	3.10	1.20	670	216	192.2	155.9	94	125.0	37	63	11	89	58	72
I	1.98	2.20	1536	776	543.2	467.6	165	316.3	32	68	30	70	41	60
I	6.90	2.20	1536	223	129.3	103.9	72	88.0	43	57	42	58	39	47
I	4.08	2.20	1536	376	304.6	240.6	140	190.3	35	65	19	81	51	64
F	6.90	2.20	1536	223	149.4	111.9	60	86.0	33	67	33	67	39	50
F	3.24	1.20	670	207	159.4	128.1	96	112.1	41	59	23	77	54	62

F - Fluorescein
I - Isotopes

INVESTIGATIONS OF THE FLOCCULATION PROCESSES

The general object of the field flocculation studies were to compare the results obtained on a full technical scale with results acquired on a laboratory scale, using mainly the Calgon flocculating agent. It was proposed that the investigations would find the basic relationships necessary for the planning of a system to purify mine waters using the cationic flocculants of the Calgon M-502 type. To be evaluated was the dependence of purification on:

- the type of flocculant
- the size of dose
- mixing method
- retention time in sedimentation basin
- atmospheric conditions

The main indicator used to measure purification was turbidity which was measured directly on the site in water samples taken at the inlet and outlet of the sedimentation basin. In addition full and shortened physico-chemical analyses of treated waters and microscopic analyses of suspended particles were made.

In the tests two cationic flocculants were used, Calgon M-502 of American production and Rokrysol WF-5 of Polish production, both manufactured in a fluid form. Polish flocculants are produced in 6-7% solution. Prior to dosing to the mine water, the flocculants were diluted with pure water to 0.1-0.5% concentration, dependent on dose used. The preparation of the solution took place in a tank with a capacity of 200 l and equipped with a manual agitator. The tank was filled with water from the supply system and after addition of a weighed portion of flocculant, the solution was mixed for 20-30 minutes for Rokrysol, and for about 1-2 hours for Calgon and then poured into the reservoir for the dosing pump. A piston pump was used with an output of 0-115 l/h and with accuracy of dosing to 0.5%.

The flocculant solution was pumped through a 20 mm diameter pipeline to the well for fast mixing. The solution was introduced through three apertures directly into the stream of water flowing from the intake with a 2.5-3.0 m/sec velocity.

First fast mixing took place in the well where a layer of turbulent water 0.7-0.8 m thick and a volume of 0.9-1.0 m^3 was maintained, thus ensuring a theoretical time of fast mixing of about 15-60 secs. Further fast mixing occurred during the initial phase of the investigations, in a ditch 76 m long that delivered the water to the sedimentation basin. In the second phase of the investigations, additional mixing took place in a special chamber of where the water was mixed by air. Gradient of the ditch bottom was 4% where the velocity of flow was 1 to 4.1 m^3/min. of 0.5 to 0.9 m/sec. Hence the resultant mixing time was 80-150 m/sec. Total theoretical time of fast mixing amounted to about 1.5-3.5 min., dependent on the flow volume. To improve the conditions of mixing in the flume, partitions were erected in it that dropped the water in 5-10 cm steps. The partitions prolonged the time of mixing and increased the velocities and enabled a better dispersion of the flocculant. To achieve the effects of prolonged fast mixing to about 10 minutes, a special chamber was constructed with a capacity of 30 m^3. With it in a pipeline supplying compressor air (60 m^3/hour) was installed.

Water, after the process of fast mixing, was delivered to an initial chamber of the sedimentation basin, where slow mixing caused by gravity took place. Then the water overflowed across the whole width of the basin into the sedimentation chamber. The shape and dimensions of sedimentation chamber are given on Figure 8.

Theoretical and average real times of retention in the sedimentational chamber under different conditions are specified in Table[15].

The average real times fluctuated was between 1-15 hours, and the basin depth 1.20 m to 2.20 m.

The decanted water was removed by an overflow covering the whole width of the basin. The water passed to a pipe and then into a ditch that carried it into the river.

The investigations were comprised of test to determine purification without flocculants and with flocculant doses between 0.1-2.0 ppm. Various flows (0.82-6.9 m^3/min) and two levels of water depth in the basin were used. A short and a prolonged time of fast mixing was investigated. The effects of purification were measured in two ways:

1. Directly on site, through measurement of turbidity in water samples taken from the inlet, outlet and from two sections of the sedimentation basin every 0.5 or 1.0 hour. Measurements were made with turbidimeter of the HACH 2100 type.

2. Full and shortened analyses of water in laboratory.

Effects of the sedimentation basin were measured chiefly by the reduction in turbidity, in suspension concentration and in oxygen demand and sporadically (2-4 times in a month) by the full water analysis taken at the inlet and outlet of the basin.

In addition microscopic observations of the suspended particles were made.

During the studies the wind speed, and temperature of water and of air were measured. At the completion of the field tests, measurements were made of the thickness of sediment layer in the experimentation basin and an assessment of its granulation with the use of microscope tests carried out.

A majority of the results are considered as reliable, and are shown in tables and in the final conclusions presented graphically on Figure 1.

During the test periods a considerable variability in the quality of the water discharged from the mine occurred. This was connected with, among other things, the change in geological and hydrogeological conditions of the deposit, which necessitated changes in the drainage technology within the mine. Part of the deposit to be excavated from the end of 1976 to about 1982 occurs at a much lower level than the part mined during the study. Excavation to this level has caused an increase in inflows, especially those flowing over the formations located below the lignite seam, which are made up of fine and dusty sand fractions. Drawing down the deposit floor has made gravitational drifts impossible for draining all water to the central pumping station and it was necessary to construct intermediate pumping stations. Considerable waterlogging of the bottom of the working greatly hindered the excavation of proper reservoirs for the pumping stations. This caused an increase in the quantity of particularly minute suspensions in the waters delivered to the reservoir situated by the central pumping station. The effect was an increase in the content of fine colloidal particles and an alteration of the relationship between turbidity and the quantities of suspensions during the year 1977 in comparison to 1976. The change in water quality had a significant impact on purification. The suspended solids-turbidity relationship for 1976 and 1977 are shown in Figure 25. In the year 1976 turbidity of the water was within the range 30-50 NTU and most often between 35-45 NTU. In one case the turbidity was 90 NTU and was caused by a reserve pump with its sucking pipe immersed into the silt. The quantity of suspended matter varied from 40 to 250 ppm with the prevalance being mineral suspensions, sometimes close to 100%, but mostly from 40 to 80%. Oxygen demand varied within the limits from 8-30 ppm of O_2, except for one time when it amounted to 140 ppm O_2. This sample was the same one with a turbidity of 90 NTU. The remaining parameters of pollutions did not deviate from average for waters of the mine Adamow and their values are tabulated in Tables 16 and 17.

In the year 1977 the turbidity of mine waters rose to 50-120 NTU, most being 50-70 NTU. The quantity of suspended matter was 40-280 ppm with the prevalance of mineral suspensions the same as in 1976. The oxygen demand varied from 15 to 70 ppm O_2 and was much higher than in 1976. The remaining parameters of pollutants as a rule did not deviate from those occurring in waters during 1976 (Tables 16 and 17).

Results of Tests with Calgon M-502

The tests using Calgon M-502 were performed from April 1976 to July 1977. Ten series of measurements were performed. In each series 4 to 6 tests were made using different flocculant doses and in some series different methods of fast mixing were utilized. Total number of tests was approximately 60 from which 51 were used in the report. In each test an average of 8-20 values of turbidity of the inlet, and the outlet water were taken. For each measurement 2-3 shortened analyses were obtained and sporadically a full analyses was conducted. A total of 80 shortened and 18 full analyses were run. Results of the tests are provided in Table 17 and on Figures 33-52. The chemical analyses are shown in Tables 16, 17 and 18.

Results Obtained With Rokrysol WF-5

Carried out in 1976 were 6 series of tests using Rokrysol WF-5 (6% concentration) in doses of 5-30 ppm. This flocculant was dosed as a 1.2-7.0% solution. Inflow of mine waters to the sedimentation basin during the tests was constant and at a rate of 4.08 m^3/min. The depth of water in the basin was 2.20 m, and the average real time of retention was about 5 hours.

The influent water had a turbidity within the 30-48 NTU range, and suspended solids of 35-135 ppm. After passing through the sedimentation basin, and without the use of the flocculant, the reduction in turbidity was small and amounted to only 3-20%. The effluent turbidity fluctuated within the limits of 28-38 NTU, i.e., about 30-60 ppm of suspended solids. Turbidity of effluent water with the addition of the flocculant, dependent on the flocculant dose, was 20-25 NTU, and the suspended solids 19-30 ppm. Optimum results were achieved with a dose of 20 ppm. Reduction in turbidity was then 55%, and the outlet turbidity amounted to 20-22 NTU, corresponding to about 20 ppm of suspensions. In these tests gravitational mixing was used in the inlet well and in ditch equipped with cross-partitions, delivering water to sedimentation basin. Approximate time of fast mixing was determined to be 2-3 minutes. Reduction in oxygen demand, when a 10 ppm dose, amounted to 50% (a decrease from 17.0 to 7.8 ppm of O_2 value). This method of purification had no influence on the remaining physico-chemical parameters of the mine waters.

The field results which revealed the optimum dose rate of flocculant to be 20 ppm was in agreement with the laboratory tests, where the optimum dose was considered to be within the 10-20 ppm range.

When a comparison was made of the results obtained in the full scale sedimentation basin "Teleszyna" with a water retention of 4-5 days, to the results obtained with the optimum dose treatment, it was found that almost identical effluent turbidities were obtained.

In 1977, the tests were repeated with the application of Rokrysol WF-5 in doses from 2 to 17 ppm, and with a solution concentration similar to that used in 1976. Gravitational mixing in ditch and a prolonged fast mixing (10 minutes) with the help of air in a special chamber was used.

The results of tests were comparable with obtained results in 1976, despite the changes in physico-chemical composition of mine waters. The turbidity in mine waters in this period amounted to 60-90 NTU, and the quantity of suspensions was 60-190 ppm. After passing through experimental sedimentation basin, with no flocculants used, the turbidity subject to effluent fluctuated from 30 to 90 NTU (reduction 0-50%). After application

Table 16. COMPREHENSIVE SPECIFICATION OF RESULTS OF MINE WATERS PURIFICATION TESTS IN SEDIMENTATION BASIN WITH THE USE OF CALGON M-502 FLOCCULANT

No. of test	Year of test performance	Amount of inflow to sedimentation basin	Filling in sedimentation basin	Average real retention time in sedimentation basin	The method of mixing	Dose of flocculant	Used flocculant solution concentration	Pollution parameters of water inflowing to sedimentation basin			Pollution parameters of outflowing waters from sedimentation basin, with no floc.		Pollution parameters of outflowing waters from sedimentation basin after adding floc.			Turbidity reduction in sedimentation basin		Reduction in COD in sedimentation basin after adding flocculant	Reduction difference after adding flocculant
								Turbidity	Approximate quantity of suspensions	Oxygen consumption	Turbidity	Approximate quantity of suspensions	Turbidity	Approximate quantity of suspensions	Oxygen consumption	With no flocculant added	With flocculant added		
		m/min	m	hour		ppm	%	NTU	ppm	ppm O_2	NTU	ppm	NTU	ppm	ppm O_2	%	%	%	%
1C	1976	7.14	2.20	10	G	0	-	48-53	251	32	23	21	-	-	-	54	-		-
2C						1.5	0.2	40-43	68	6.8	21-22	20*	10-11	7*	-	50	74	-	24
3C						1.0	0.1	51	68	8.8	18	11	11-12	5	4.6	65	77	48	12
4C						0.75	0.1	42-43	63	8.0	17-18	14	11	8*	-	59	74	-	15
5C						0.50	0.1	42-44	86*	-	23-24	24*	18-20	17*	-	45	56	-	11
6C						0.25	0.1	44-47	105*	-	21-22	20*	18-20	17*	-	53	58	-	5
7C	1976	4.98	2.20	5	G	2.0	0.5	34-40	73*	-	32-33	43*	12	traces^{9}*	7.0	12	68	-	56
8C						1.5	0.4	35-37	53*	-	28-32	35*	12	9*	-	17	67	-	50
9C						1.0	0.4	36	53*	-	28-32	35*	12	9*	-	17	67	-	50
10C						0.75	0.2	42-43	83*	-	27-28	31*	13	10*	-	35	69	-	34
11C						0.50	0.2	41-42	77*	-	40	70*	26	28*	-	4	37	-	33
12C	1976	3.49	2.20	15	G	2.0	0.1	43-44	90*	-	19-20	18*	10	traces^{7}	6.6	55	78	-	23
13C						1.5	0.1	43	52	20	20-24	21*	10	traces^{7}	7.8	49	77	61	28
14C						1.0	0.1	35-38	60*	-	32-33	43*	15	12*	-	13	60	-	47
15C						0.75	0.1	36-37	55*	-	24-25	26*	13	10*	-	33	64	-	31
16C	1976	0.92	1.20	9.8	G	1.5	0.1	32-33	96	30.5	-	-	14	9	6.8	-	57	78	
17C						1.0	0.1	41	75*	-	17	15*	12	15	6.2	58	71	-	13
18C						0.75	0.1	33	99	27.0	27	30*	16-27	12	6.2	18	50	77	32
19C						0.50	0.1	38	92	39.0	33	45*	22	24	7.6	13	42	80	29
20C	1976	3.1	1.20	3.2	G	1.5	0.4	41	67	18.7	37	58*	17	16	7.2	10	58	61	48
21C						1.0	0.2	33-37	57	20.7	32-33	43*	18	14	7.8	7	49	62	42
22C						0.75	0.2	90	250	140.0	63-88	-	28	22	10.6	16	69	92	53
23C						0.50	0.1	43	73	19.2	31-38		21-23	27	8.0	20	49	58	29
24C	1976	6.9	1.20	1.7	G	1.5	0.5	40-42	92	13.2	31-38		18-20	22	7.9	0	54	40	54
25C						1.0	0.5	39	101	16.4	39		23	32	9.7	0	41	41	41
26C						0.75	0.5	42	220	19.5	42		23	24	9.1	0	44	53	44
27C						0.50	0.5	42	86	16.0	41		30	66	13.6	2	29	15	27
28C	1976	4.08	2.20	5	G	1.0	0.4	33-34	-	-	33-34		23		-	0	31		31
29C	1977	4.08	2.20	5	G	4.0	1.0	55	54	16	38	39*	17	4	4.8	31	69	70	38
30C					P	4.0	1.0	62-63	60	18	53	58*	23	21	7.2	15	63	60	48
31C					G	1.5	0.4	70-72	70	20	53	58*	30	30	9.6	25	58	52	33
32C					P	1.5	0.4	75-76	115	40	65-69	82*	32	20	7.4	11	58	81	47
33C					G	0.5	0.2	63-64	57	22	49-51	52*	38-39	39	11.2	21	39	49	18
34C					P	0.5	0.2	61-62	70	18	57-58	65*	40	52	8.8	7	35	51	28
35C	1977	1.95	2.20	9	G	1.5	0.2	85-86	137	36	36-38	36*	34-35	21	12.0	57	60	67	3
36C						1.0	0.25	57	58	28	44	45*	29	17	6.8	23	49	76	26
37C						0.75	0.1	51	42	18	41-42	46	36	29	13.2	19	26	32	7
38C						0.5	0.1	59-61	34	12	45-46	37	41-42	26	12	24	31	-	7
39C	1977	0.82	2.20	~15	G	2.0	0.1	45-53	68	19	16-27	30	16-17	18	6.8	66	66	64	0
40C						1.0	0.1	48-52	54*	11	22-24	20*	16-17	19	6.6	54	67	40	13
41C						0.5	0.1	50-64	102	37	19-22	18*	19-22	15	7.6	64	64	79	0
42C	1977	3.1	1.20	3.2	G	2.0	0.4	70	144	18	52-57	106	23	24	7	22	67	61	45
43C					P	2.0	0.4	82-85	140*	-	66-68	85	21-23	15	7.4	20	74	-	54
44C					G	1.5	0.4	92	152	56	57	81	43	56	19.2	38	53	66	15
45C					P	1.5	0.4	98	133	66	69-72	127	44	45	13.5	27	55	79	28
46C					G	1.0	0.2	57	64	26	36-39	55	26	30	6	34	54	77	20
47C					P	1.0	0.2	71-72	115	13.2	50-51	55*	24	21*	7	29	66	50	37
48C					G	0.75	0.2	98-110	271	40	82-83	93	55-59	52	22.4	21	45	44	24
49C					P	0.75	0.2	100-120	185	48	94-96	160	49-60	64	18.4	14	50	62	36
50C					G	0.50	0.2	110-115	291	46	91-95	197	62	52	2.3	17	45	50	28
51C					P	0.50	0.2	90-94	282	50	70	86	47-54	67	23.6	24	45	53	21

* - content of suspension read from curve of relationships between turbidity and quantity of suspensions

G - gravitational mixing in ditch offtaking water to sedimentation basin

P - mixing in special chamber with air

TABLE 17. SPECIFICATION OF RESULTS OF WATER SAMPLES PHYSICO-CHEMICAL ANALYSES FROM FIELD TESTS OF CALGON M-502 APPLICATION

Type of Pollutant	Unit	No. of test and place of sampling: 3C inlet	3C outlet	7C outlet without flocculant	17C inlet	20C inlet	20C outlet	27C inlet	27C outlet	34C inlet	34C outlet	40C inlet	40C outlet without flocculant	40C outlet after add. flocculant	42C inlet	42C outlet after add. flocculant	43C outlet without flocculant	43C outlet after add. flocculant	
Turbidity	ppm	45	11	33	33	260	[illegible]	160	15	250	170	80	40	40	-	-	15	-	15
Color	ppm	25	10	20	40	30	35	30	30	-	-	20	20	20	15	25	15	15	25
Smell		1Veg	1Veg	1Veg	1Veg	1Veg	1Veg	1Veg	1Veg	1Veg	1Veg	2Spec	2Spec	2Spec	1Veg	1Veg	1Veg	1Veg	1Beg
Reaction	pH	7.8	7.9	7.4	6.7	7.0	8.2	8.0	8.0	6.9	7.2	-	-	-	7.6	7.6	7.6	7.6	7.6
Alkalinity	mval/l	4.2	4.3	4.2	4.1	3.6	3.7	3.8	3.9	3.5	3.7	3.8	4.0	4.0	3.9	4.0	4.1	4.0	3.9
Total hardness	deg.	16.9	16.9	16.0	18.1	17.0	17.2	17.0	16.8	18.6	19.0	19.0	19.2	20.0	19.8	20.1	19.6	21.2	20.6
Non-carbonate hardness	deg.	11.8	12.0	4.2	6.9	6.9	7.0	6.4	5.9	8.8	10.6	8.6	8.0	8.8	8.9	8.9	8.0	10.0	9.7
Carbonate hardness	deg.	5.1	4.9	11.8	11.5	10.1	10.4	10.8	10.9	8.8	8.4	10.4	11.2	11.2	10.9	11.2	11.6	11.2	10.9
Total iron	ppm Fe	0.2	traces	1.0	0.1	0.10	0.05	0.3	0.02	0.6	0.3	2.3	1.34	1.4	0.48	0.22	traces	0.54	0.12
Manganese	ppm Mn	0.08	0.08	traces	traces	traces	traces	n.det.	0.14	n.det.	traces	0.2	0.17	0.15	-	-	-	-	-
Chlorides	ppm Cl	40	40	47	30	39.0	43.0	43.0	44.0	46.0	48.0	49.0	49.0	47.0	50.0	50.0	48.0	52.0	50.0
Ammonia	ppm N	0.05	0.3	0.3	0.1	0.5	0.4	0.6	2.0	0.7	0.8	0.7	0.5	0.6	2.4	3.0	2.2	2.4	0.3
Nitrites	ppm N	0.002	0.003	0.005	0.02	0.03	0.02	0.02	0.03	0.02	0.02	0.015	0.015	0.015	0.03	-	-	0.006	0.01
Nitrates	ppm N	traces	traces	traces	traces	n.det.	n.det.	n.det.	n.det.	n.det.	n.det.	n.det.	n.det.	n.det.	-	-	-	-	-
Oxygen consumption	ppm O_2	8.8	4.6	13.6	28.8	18.7	7.0	13.0	7.0	18.0	8.8	11.0	6.4	7.6	18.0	10.5	7.0	15.5	7.4
Dissolved solids	ppm	408	393	430	644	498	480	416	447	543	546	613	688	630	636	575	585	617	643
Dissolved mineral substances	ppm	338	323	370	527	420	380	380	374	474	462	487	501	500	500	480	477	476	481
Dissolved volatile substances	ppm	70	70	60	117	78	100	36	73	69	84	126	187	130	136	95	108	141	162
Sulfates	ppm SO_4	128	118	61.5	142	108.9	107.0	93.0	86.9	185	170	153	155	163	163	156	147	174	171
Total suspended solids	ppm	68	8	73	50	67	16	90	30	70	52	133	95	85	144	106	24	85	15
Mineral suspensions	ppm	64	5	47	20	0	16	54	8	31	23	125	51	67	121	62	21	59	9
Volatile suspensions	ppm	4	3	26	30	67	0	36	22	39	29	8	44	18	23	44	3	26	6
Calcium	ppm Ca	88.4	88.4	89.9	100.8	88.6	94.1	89.9	91.3	104.6	104.6	107.0	112.7	112.7	116.9	109	112.7	91	117
Magnesium	ppm Mg	19.5	18.3	14.5	13.0	21.4	18.0	18.0	17.0	4.0	4.4	17.0	14.5	18.0	14.5	20.5	12.0	36	18
Sodium	ppm Na	28.0	29.0	21.0	16.0	20.0	20.0	20.0	22.0	41.0	40.0	28.0	31.0	29.0	32.0	31.0	32.0	32.0	32.0
Potassium	ppm K	2.9	3.0	0.0	0.7	0.75	0.65	0.7	9.0	4.0	12.0	16.0	13.0	8.0	5.0	5.0	5.0	5.0	5.0
Balance of Electrolytes: A N I O N S																			
HCO_3^-	mval/l	4.2	4.3	4.2	4.1	3.6	3.7	3.8	3.9	3.5	3.7	3.8	4.0	4.0	3.9	4.0	4.1	4.0	3.9
Cl^-	mval/l	1.128	1.128	1.330	0.850	1.100	1.213	1.213	1.241	1.297	1.354	1.38	1.38	1.35	1.410	1.410	1.354	1.467	1.410
$SO_4^{=}$	mval/l	2.666	2.457	1.28	2.960	2.269	2.228	1.936	1.811	3.852	3.539	3.19	3.23	3.39	3.394	3.248	3.061	3.623	3.560
NO_3^-	mval/l	-	-	0.15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	mval/l	7.993	7.885	6.960	7.910	6.960	7.141	6.949	6.952	8.649	8.593	8.37	8.61	8.74	8.704	8.658	8.515	9.090	8.870
Balance of Electrolytes: C A T I O N S																			
Ca^{++}	mval/l	4.422	4.403	4.483	5.490	4.279	4.707	4.493	4.564	5.206	5.206	5.35	5.63	5.63	5.848	5.456	5.634	4.564	5.848
Mg^{++}	mval/l	1.606	1.533	1.212	1.070	1.783	1.498	1.564	1.426	1.426	1.564	1.43	1.21	1.50	1.212	1.712	1.355	2.995	1.498
Na^+	mval/l	1.218	1.261	0.913	0.700	0.870	0.870	0.870	0.957	1.783	1.739	1.22	1.35	1.26	1.392	1.348	1.392	1.392	1.392
K^+	mval/l	0.077	0.077	0.000	0.020	0.026	0.026	0.026	0.026	0.23	0.102	0.31	0.41	0.34	0.205	0.128	0.128	0.128	0.128
Total	mval/l	7.323	7.364	6.628	7.280	6.958	7.101	6.953	6.973	8.645	8.611	8.31	8.60	8.73	8.702	8.644	8.509	8.079	8.866

Table 18 COMPREHENSIVE SPECIFICATION OF WATER PARTICAL ANALYSES FROM FIELD TESTS, WITH APPLICATION OF CALGON M-502

No. of test	Place of tested sample taking	Oxygen consump. ppm O_2	Suspension ppm General	Suspension ppm Mineral	Suspension ppm Organic
1C	Inlet	32	251	191	60
1C	outlet, without flocculant	6.0	21	19	2
2C	Inlet	6.8	68	46	22
3C	outlet, with flocculant	4.8	11	11	3
4C	Inlet	8.0	63	52	11
7C	outlet, with flocculant	7.0	traces	---	---
12C	outlet, with flocculant	6.6	traces	---	---
13C	inlet	20	52	18	34
13C	outlet, with flocculant	7.8	traces	---	---
16C	inlet	30.5	96	32	64
16C	outlet, with flocculant	6.8	9	3	6
17C	outlet, with flocculant	6.2	45	8	7
18C	inlet	27	99	35	64
18C	outlet, with flocculant	6.2	12	8	4
19C	inlet	39	92	40	52
19C	outlet, with flocculant	7.6	24	14	10
21C	Inlet	20.7	57	---	---
21C	outlet, with flocculant	7.8	14	---	---
22C	Inlet	140.0	2.59	106	153
22C	outlet, with flocculant	10.6	22	22	0
23C	Inlet	19.2	73	53	20
23C	outlet, with flocculant	6.0	27	---	---
25C	inlet	16.4	101	11	90
25C	outlet, with flocculant	9.7	32	30	2
26C	inlet	19.5	2.20	194	26
26C	outlet, with flocculant	9.1	24	12	12
27C	Inlet	16.0	86	35	51
27C	outlet, with flocculant	11.6	66	3	63
29C	Inlet	16	54	23	31
29C	outlet, without flocculant	9.2	39	29	10
29C	outlet, with flocculant	4.8	4	---	---
30C	Inlet	18	40	31	9
30C	outlet, with flocculant	7.2	21	12	9
31C	Inlet	20	70	33	37
31C	outlet, with flocculant	9.4	30	23	7
32C	Inlet	4.5	115	65	50
32C	outlet, with flocculant	7.4	20	17	3
33C	Inlet	22	57	49	8
33C	outlet, with flocculant	11.2	39	23	16
35C	Inlet	35.0	13.7	75	62
35C	outlet, with flocculant	12.0	21	17	4
36C	Inlet	28	58	41	17
36C	outlet, with flocculant	6.8	17	12	5
37C	Inlet	18.0	42	23	19
37C	outlet, without flocculant	18.0	46	26	20
37C	outlet, with flocculant	13.2	29	18	11
38C	inlet	12.8	34	21	13
38C	outlet, without flocculant	14.0	37	33	4
38C	outlet, with flocculant	12.0	26	18	8
39C	inlet	19.0	68	48	20
39C	outlet, without flocculant	7.6	30	11	19
39C	outlet, with flocculant	6.8	18	13	5
40C	outlet, with flocculant	6.6	19	12	7
41C	inlet	37.0	102	56	46
41C	outlet, without flocculant	7.6	41	31	10
41C	outlet, with flocculant	7.6	15	3	12
44C	Inlet	56.0	152	127	25
44C	outlet, without flocculant	21.6	81	62	19
44C	outlet, with flocculant	19.2	56	45	11
45C	inlet	66.0	133	91	42
45C	outlet, without flocculant	56.0	127	117	10
45C	outlet, with flocculant	13.5	45	35	10
46C	Inlet	26.0	64	---	---
46C	outlet, without flocculant	8.0	55	46	9
46C	outlet, with flocculant	6.0	30	22	8
47C	inlet	13.2	115	105	9
47C	outlet, without flocculant	13.2	---	---	---
47C	outlet, with flocculant	7.0	---	---	---
48C	inlet	40.0	271	193	78
48C	outlet, without flocculant	19.6	93	65	28
48C	outlet, with flocculant	22.4	52	37	15
49C	inlet	48.0	185	163	22
49C	outlet, without flocculant	40.0	160	111	49
49C	outlet, with flocculant	18.4	64	37	27
50C	inlet	4.60	291	205	85
50C	outlet, without flocculant	32.0	197	143	54
50C	outlet, with flocculant	23.0	52	24	28
51C	inlet	50.0	282	184	98
51C	outlet, without flocculant	43.0	86	63	23
51C	outlet, with flocculant	23.6	67	56	11

of flocculant in doses of 2-17 ppm, reduction in turbidity increased and amounted to 31-67%. Better effects of purification were achieved employing a prolonged process of fast mixing. Reduction in turbidity in these test series was higher by 15-30%.

Optimum results were obtained using a Rokrysol dose of 17 ppm and prolonged fast mixing. During the performance of this test a very difficult water to purify was occurring. In some measurements during this test, it was found that plain sedimentation with 5 hours of retention produced no noticeable reduction in turbidity. After application of flocculant, the turbidity was decreased to the 37-42 NTU level, corresponding to a suspended solids of under 40 ppm. The mine water during performance of these tests was characterized with a high oxygen demand (15-78 ppm O_2). After passing through the sedimentation basin with the optimum dose of flocculant, the oxygen consumption was reduced by 74% with application of prolonged fast mixing, and 63% with gravitational mixing only. Without the use of flocculants, the oxygen demand after passing through the basin was within reduced limits of 20-40%.

The remaining parameters of the water did not undergo substantial changes with the exception of a small reduction in iron.

During the performance of tests no influence of temperature was observed on the effects of purifying the water with the application of flocculant, which is agreement with laboratory investigations and with literature.

Results of these tests with the application of Rokrysol are specified in Tables 19, 20 and 21 and in Figures 53-57.

TABLE 19. RESULT OF MINE WATER PURIFICATION FIELD TESTS IN SEDIMENTATION BASIN, WITH THE FLOCCULANT ROKRYSOL WF-5

No. of test	Year of test performance	Inflow quantity to sedimentation basin	Filling in sedimentation basin	Average real time of retention in sedimentation basin	Method of mixing	Flocculant dose	Concentration of employed flocculant solution	Pollutant parameters of waters flowing to sedimentation basin			Pollutant parameters of outlet waters from sed.basin without added flocculant			Pollutant parameters of outlet waters from sed. basin w/added floc.			Turbidity reduction in sedimen. basin		Oxy.cons. reduction in sed. basin		Difference in suspension reduction after adding flocculant
								Turbidity	Approx. suspensions quantity	Oxygen consumption	Turbidity	Approximate suspensions quantity	Oxygen consumption	Turbidity	Approximate suspensions quantity	Oxygen consumption	Without adding flocculant	After adding flocculant	Without adding flocculant	After adding flocculant	
1R	1976	4.08	2.2	5	G	0	-	38	63	14.2	34	59	11.8	-	-	-	11	-	17	-	-
2R						5	1.22	34-35	40	11.0	30	48	8.8	20-25	16-26	6.8-8.2	13	35	20	32	22
2R						5	1.22	34-35	40	11.0	30	48	8.8	20-25	16-26	6.8-8.2	13	35	20	32	22
3R						8.2	3.34	30	35*	nt	28-29	32*	nt	20-22	20*	nt	5	30	-	-	25
4R						10	2.45	45	124	170	30-33	52	13	23	8	7.4	30	49	23	59	19
5R						20	4.9	46-48	135*	nt	32-38	58*	nt	20-22	20*	nt	25	55	-	-	30
6R						30	7.0	37-40	64*	nt	29-33	42*	nt	20-23	21*	nt	17	44	-	-	27
7R	1977				G	0	-	40-43	48	16.8	22-30	7	8.6	-	-	-	37	-	58	-	-
8R					P	0	-	61-62	58	25	43-45	35	14	-	-	-	28	-	44	-	-
9R					G	2	1.67	57-60	46	15	33	24*	nt	24-26	11	8.6	43	57	-	43	14
10R					P	2	1.67	63-69	125	23	33	24*	nt	25-26	39	11.2	50	61	-	51	11
11R					G	4.2	3.34	84-85	145	62	74-75	98	56	55	40	26	12	35	10	58	23
12R					P	4.2	3.34	74	130	19	55-56	35	13	24-30	32	10	25	64	32	47	39
13R					P	8.2	3.34	84-85	198	74	52	45*	10	30	60	7.0	38	65	86	91	27
14R					G	16.7	6.8	96	238	78	88-89	96	76	65-67	59	26	8	31	3	67	23
15R					P	16.7	6.8	85-89	174	58	86	126	nt	37-42	40	15	0	55	-	74	55
16R					G	0	-	88-91	144	78	84-85	119	60	-	-	-	6	-	23	-	-

* - content of suspension read from curve of relationships between turbidity and quantity of suspensions.
G - gravitational mixing in ditch offtaking water to sedimentation basin
P - mixing in special chamber with air.

Table 20 RESULTS OF WATER SAMPLE ANALYSES, FROM FIELD TESTS WITH THE APPLICATION OF ROKRYSOL WF-5

Type of pollutants	Unit	No. of test and place of sampling 2 R inlet	2 R outlet	9 R inlet	9 R outlet	13 R inlet	13 R outlet
Turbidity	ppm S_1O_2	110	45	210	100	600	20
Colour	ppm	20	20	20	15	---	---
Smell		1 Veg	1 Veg	1 Veg	1 Veg	1 Veg	1 Veg
Reaction	p H	7.8	8.0	7.8	7.8	7.4	7.4
Alkalinity	mval/l	3.3	3.3	3.5	3.8	3.7	3.7
Total hardness	deg	18.0	17.3	21.0	20.0	20.5	20.0
Non-carbonate hardness	deg	8.8	8.1	11.2	9.4	10.1	9.6
Carbonate hardness	deg	9.2	9.2	9.8	10.6	10.4	10.4
Total iron	ppm, Fe	0.014	0.1	0.35	0.2	0.25	0.3
Manganese	ppm, Mn	0.1	n.det.	0.15	0.24	0.077	n. det.
Chlorides	ppm, Cl	44.0	4.8	50.0	44.0	44.0	42.0
Ammonia	ppm, N	4.0	0.4	1.4	0.008	0.008	00.15
Nitrites	ppm, N	0.02	0.02	0.028	0.028	-----	0.04
Nitrates	ppm, N	n.det.	n.det.	n.det.	n.det.	n.det.	n. det.
Oxygen consumption	ppm, O_2	11.0	6.8	15.0	7.5	7.4	7.0
Dissolved solids	ppm	512	511	613	565	540	556
Dissolved mineral substances	ppm	403	397	498	494	465	470
Dissolved volatile substances	ppm	109	114	115	51	75	96
Sulphates	ppm SO_4	121	118.9	185	181	160	159
Total suspended solids	ppm	40	16	46	27	198	60
Mineral suspensions	ppm	40	16	16	23	137	36
Volatile suspensions	ppm	0	0	30	4	61	24
Free carbon dioxide	ppm, CO_2	----	----	5.6	6.0	15.0	15.0
Aggressive carbon dioxide	ppm, CO_2	----	----	0	0	2.0	2.0
Calcium	ppm Ca	97.0	92.0	118	111	14.5	15.5
Magnesium	ppm Mg	18.0	18.8	19.2	19.0	6.0	4.5
Sodium	ppm Na	15.0	19.0	20.0	27.0	18	18
Potassium	ppm K	0.8	0.75	15.0	15	7	10
BALANCE OF ELECTROLYTES							
		ANIONS					
HCO_3^-	mval/l	3.300	3.300	3.5	3.8	3.7	3.7
Cl^-	mval/l	1.241	1.241	1.41	1.24	1.24	1.18
SO_4	mval/l	2.519	2.478	3.85	3.75	3.33	3.31
Total	mval/l	7.060	7.019	8.76	8.79	8.27	8.19
		CATIONS					
Ca^{++}	mval/l	4.850	4.600	5.88	5.56	5.17	5.53
Mg^{++}	mval/l	1.564	1.564	1.61	1.56	2.14	1.61
Na^+	mval/l	0.652	0.826	0.87	1.22	0.78	0.78
K^+	mval/l	0.026	0.026	0.38	0.38	0.18	0.26
Total	mval/l	7.092	7.016	8.74	8.82	8.27	8.18

TABLE 21. RESULTS OF WATER ANALYSES FOR OXYGEN DEMAND AND SUSPENDED SOLIDS WITH THE APPLICATION OF ROKRYSOL WF-5

No. of tests	Place of taken water sample	Oxygen Demand ppm of O_2	Suspended Solids, ppm Total	Mineral	Organic
1R	inlet	14.2	63	63	0
1R	outlet without flocculant	11.8	59	48	11
2R	outlet without flocculant	8.8	48	28	20
4R	inlet	17.0	124	80	44
4R	outlet with flocculant added	7.4	8	0	8
7R	inlet	16.8	48	24	24
7R	outlet without flocculant	8.6	7	5	2
8R	inlet	25.0	58	48	10
8R	outlet without flocculant	14.0	35	32	3
9R	outlet with flocculant added	8.6	11	6	5
10R	inlet	23.0	125	74	51
10R	outlet with flocculant added	11.2	39	17	22
11R	inlet	62.0	145	81	64
11R	outlet without flocculant	56.0	98	65	33
11R	outlet with flocculant added	26.0	40	24	16
12R	inlet	19.0	52	37	15
12R	outlet without flocculant	13.0	35	24	11
12R	outlet with flocculant added	10.0	32	20	12
14R	inlet	70.0	238	121	117
14R	outlet without flocculant	76.0	96	57	39
14R	outlet with flocculant added	26.0	59	42	17
15R	inlet	58.0	174	130	44
15R	outlet without flocculant	70.0	126	66	60
15R	outlet with flocculant added	15.0	40	30	10
16R	inlet	78.0	144	86	58
16R	outlet without flocculant	60.0	119	80	39

CHARACTERIZATION OF SUSPENSIONS

The content of the suspended matter, both mineral and organic, in the influent and effluent of the basin is specified in Tables 13, 14, 16 and 17 on the basis of physico-chemical analyses. To determine the shapes and sizes of suspension particles, in 1977 microscopic tests employing 100, 180, and 600-fold magnifications were conducted. The investigations showed the occurrence in the polluted waters of large quantities of colloidal, pseudo-colloidal and clayey particles, with 0.01 mm diameters. Particles with diameters within the 0.01 to 0.1 mm range were occurring in smaller amounts and were dependent on atmospheric conditions prevailing in the mine. After a rainy period the quantity of these particles increased. Particles with diameters above the 0.1 mm were occurring sporadically. The majority of the grains constituted particles of quartz with compact shapes approximating polyhedron. The second largest group were the suspended particles of coal with various shapes from compact, to elongated and to jagged. The size of these particles were different and up to 0.1 mm diameter. Encountered sporadically were grains with larger diameters. Also found on occasions were feldspathoid, biotite and muscovite grains and organic particles of vegetable and sewage origin. The shape and size of suspension grains in waters flowing into the sedimentation basin are shown at different magnifications in Figures 21-25. After addition of flocculating reagents, especially Calgon M-502, the floccules formed were with dimensions approaching a few mm. The shape and dimensions of floccules directly after fast mixing are shown in Figure 23 and after the process of slow mining on 24.

Water flowing from the basin also contained suspensions, the amount of which depended on the concentrations in the inflowing water, on the type and dose of flocculant, and on the time of retention. Quantity of total mineral and organic suspensions in purified waters in given in Tables 13, 14, 16, 17.

Microscopic investigations for the shape and size of these suspensions indicated that the majority of particles had diameters below the 0.005 mm with various shapes, mainly grains of quartz, mica and coal. Occurring also were smaller flocs with loose fledged structure, which had found no conditions in the sedimentation basin for their settling.

CHARACTERIZATION OF SEDIMENTS

The experimental sedimentation basin with the addition of a flocculant to the water gave a high degree of suspension reduction and a fast silting of the sediment. During the period of the tests, the sedimentation basin was desilted two times. The desilting was carried out when the average level of sediment exceeded 0.30 m. The most intensive silting occurred in the inlet half of the sedimentation chamber. In the other half the thickness of sediment was about 10 cm less in comparison with the inletting part. The average fall in grade of the sediments was about 1%. The sediment was strongly hydrated and a greater part of the basin the sediment had a

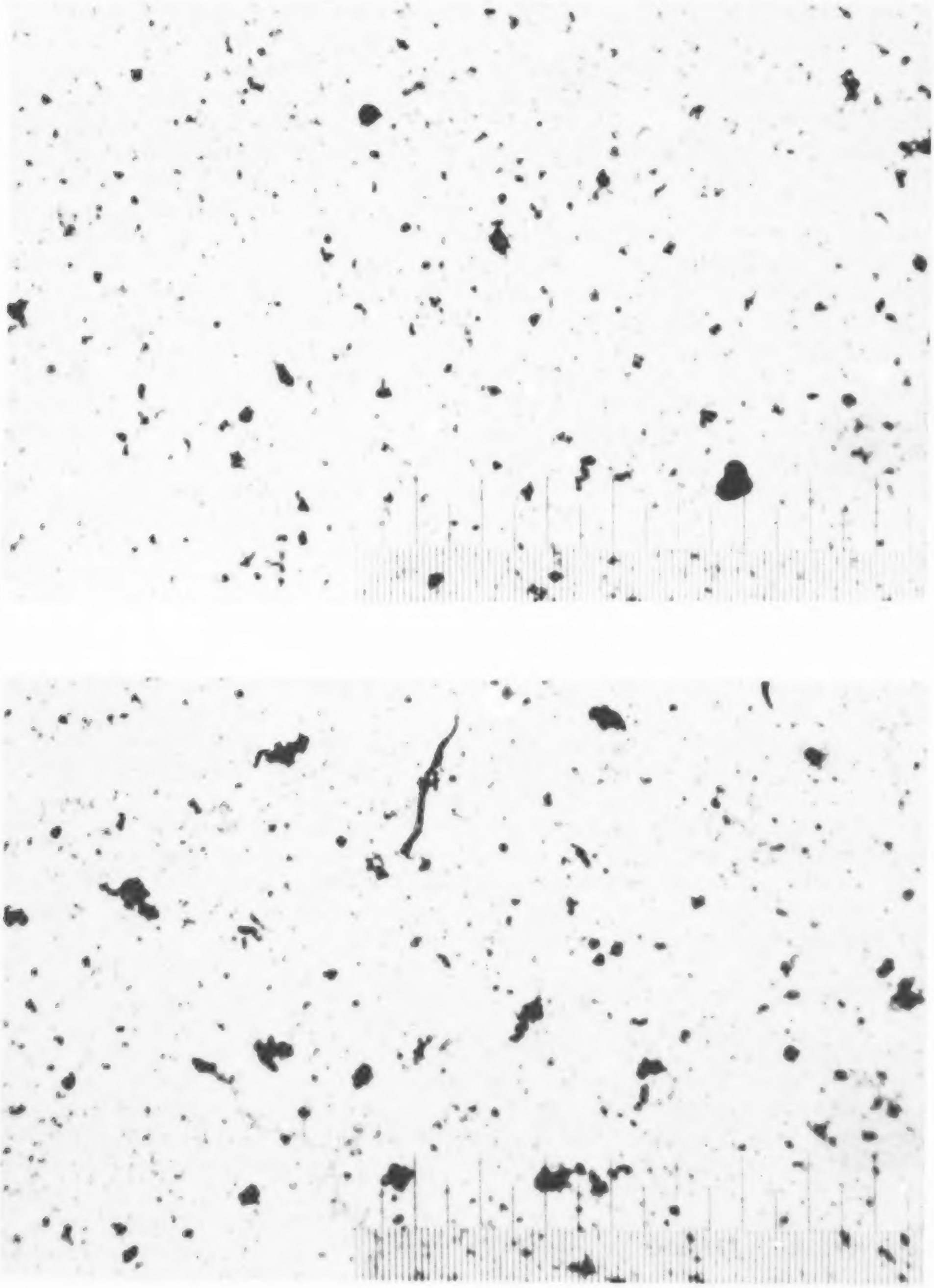


Figure 21. Suspensions in Polluted Mine Waters (100 times magnification)

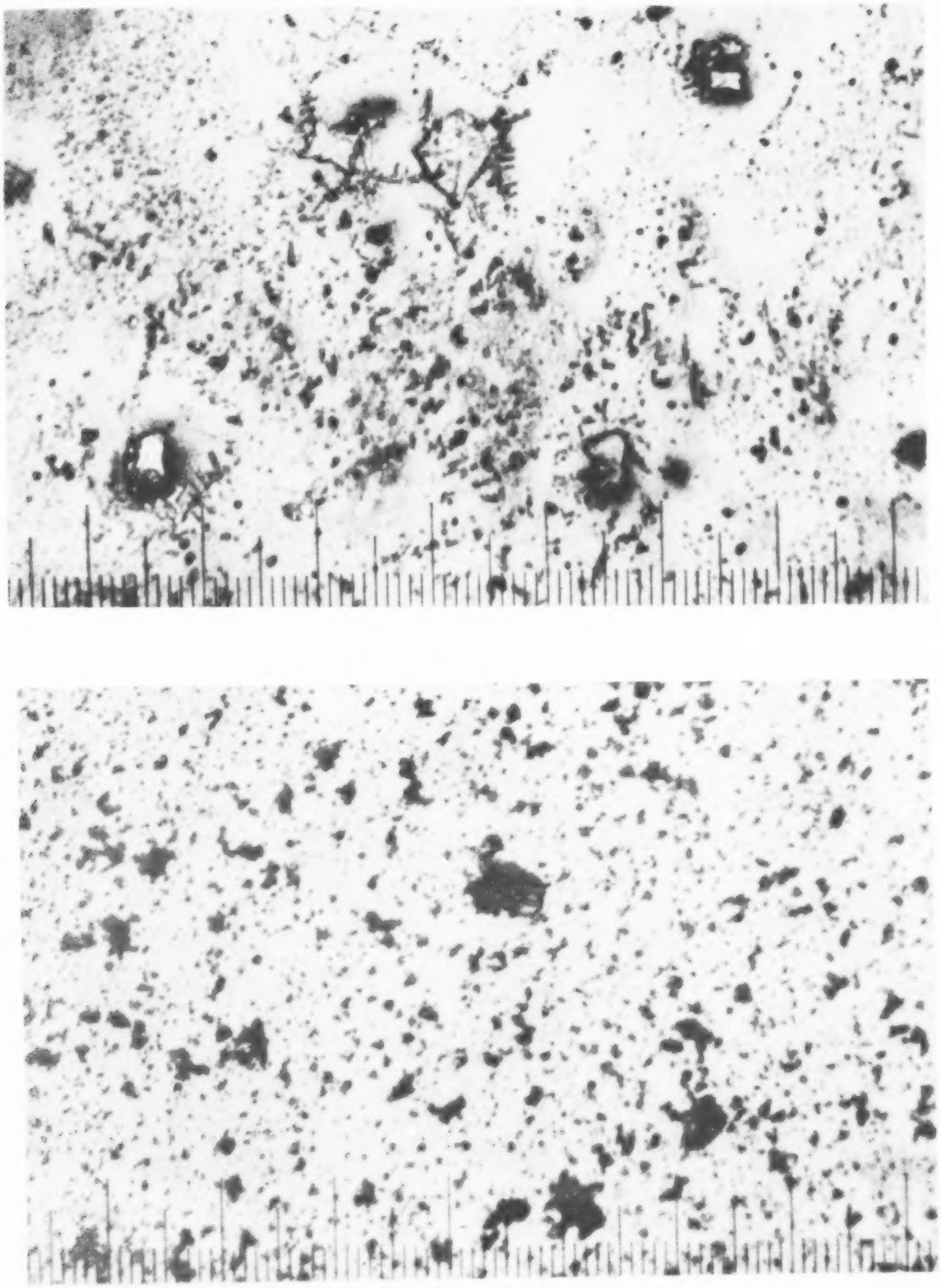


Figure 22. Suspensions in Polluted Mine Waters
(180 times magnification)

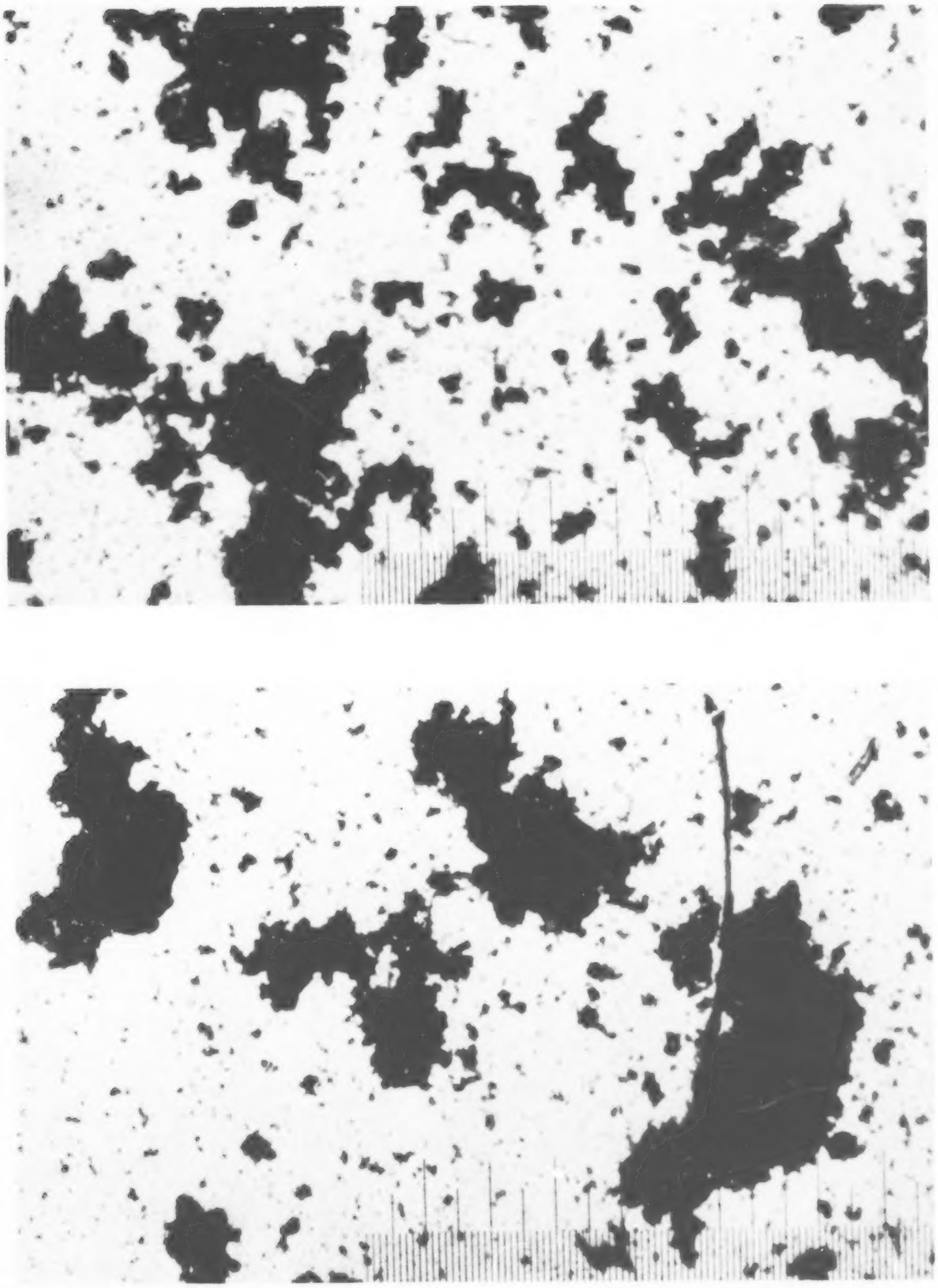


Figure 23. Suspensions in Mine Waters after Fast Mixing with Calgon M-502 Flocculant (magnified 100 times)

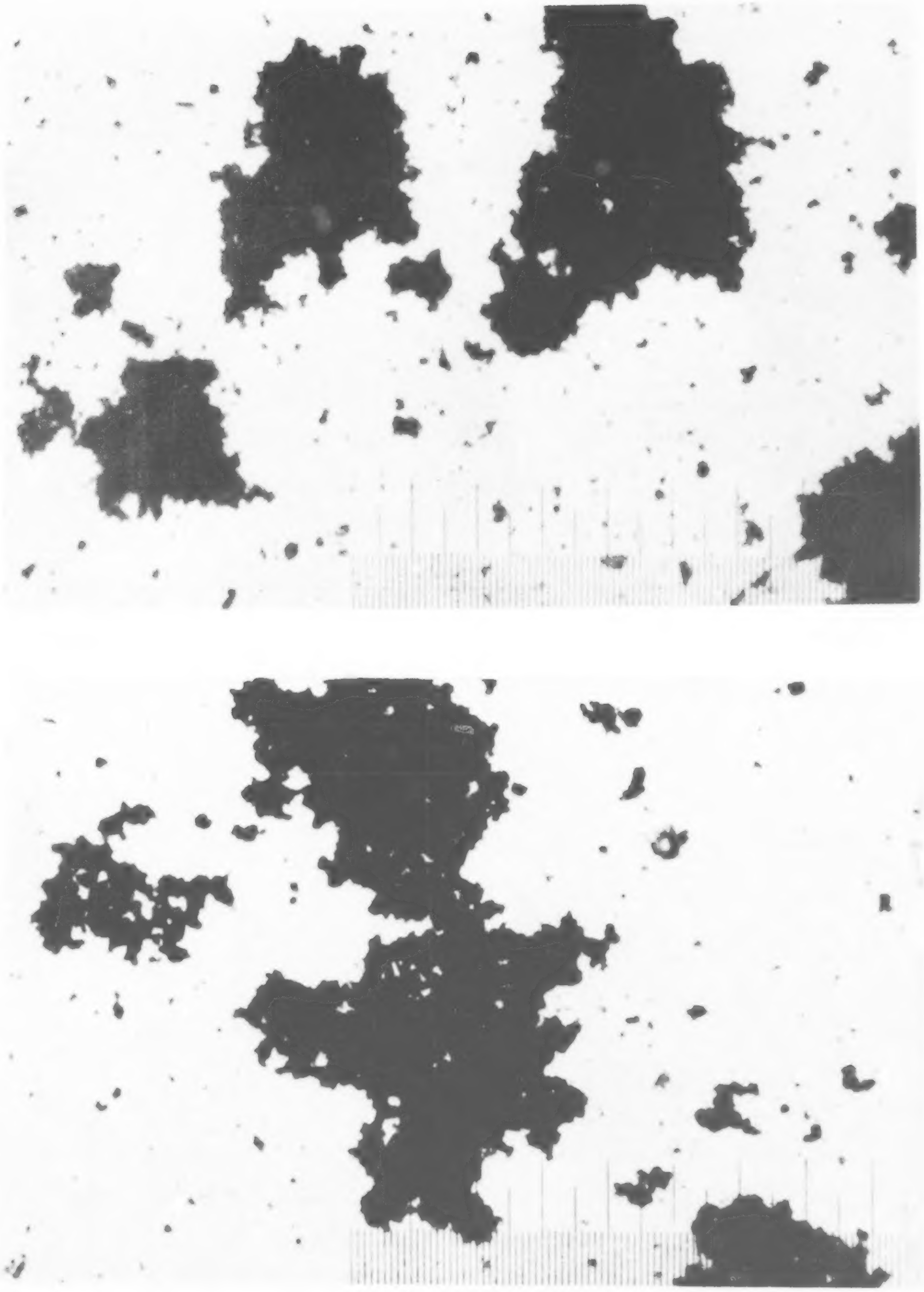


Figure 24. Flocculated suspensions in mine waters from sedimentation chamber (magnified 100 times)

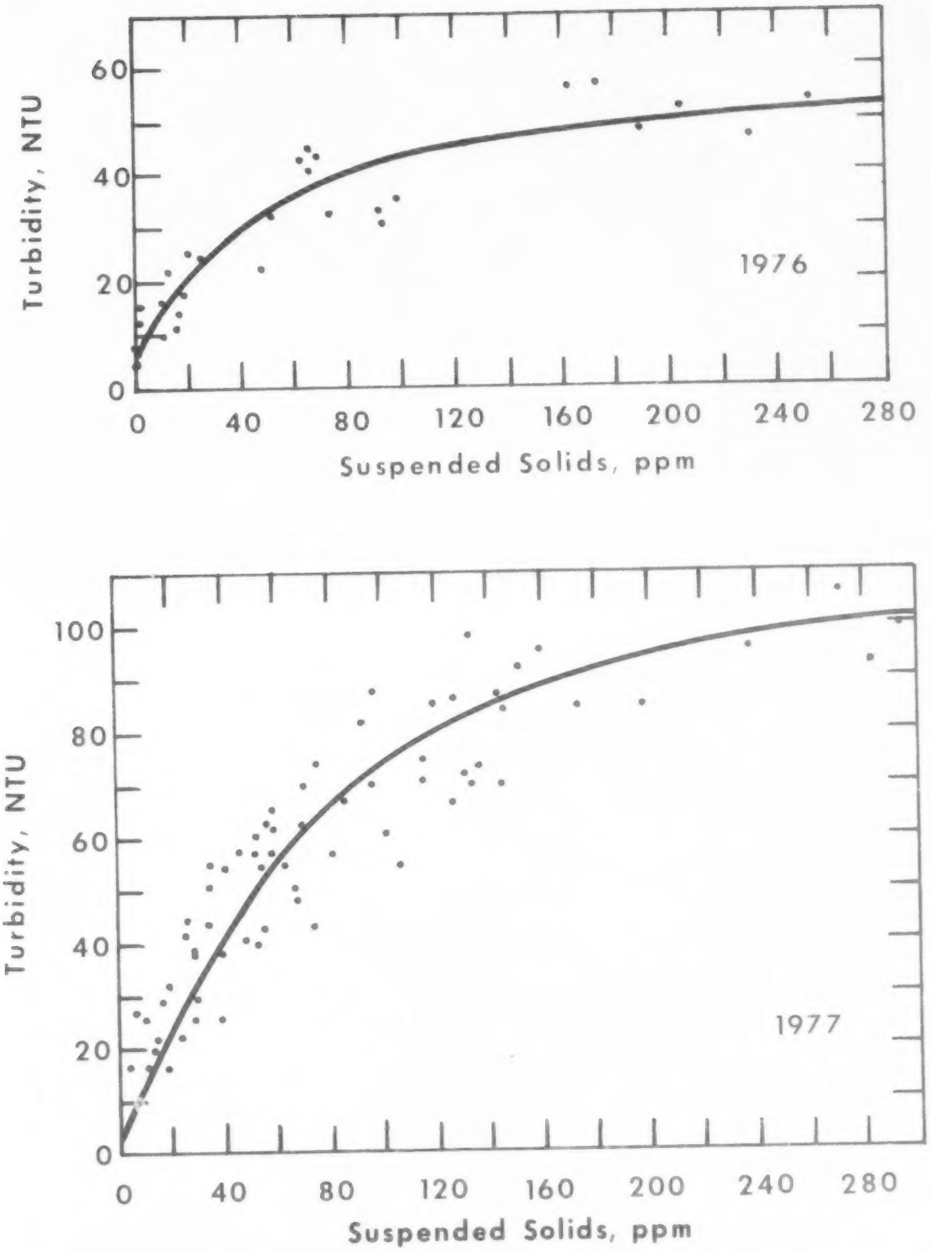


Figure 25. Relationship between suspended solids and turbidity / orientation/.

consistency of thick cream. Only in the inlet part was the consistency more dense.

Average content of solid particles in one liter of sediment was 0.033 kg of which mineral particles were 0.0303 kg and organic 0.0027 kg. Due to frequent desilting of sedimentation basin the volume of sediment was only a small percentage of total capacity of the sedimentation basin, during the time of research work (about 10%).

Under these conditions the sedimentation basin silting had no effects of purification. A greater amount of silting would without any doubt affect the active capacity of the sedimentation basin, decreasing the effect of suspension reduction with the applied dose of flocculant in accordance with the relationship presented in Figure 1. In designing a sedimentation basin one should allot appropriate size of the inletting part, not to be included as part of the active sedimentation basin capacity in accordance with recommendations regarding the designing of the sedimentation basins provided in Section 3.

COSTS OF PURIFICATION TREATMENT PLANT EXPLOITATION

A detailed analysis of the cost of treatment can be carried out for a specific system. Performed in this report was an analysis of the percentage of the treatment cost that could be assigned to different cost parameters. The design was based on a treatment plant with an output of 30 m^3/min. and with water similar to the waters drained from the surface mine Adamow. The flocculant was to be Rokrysol WF-5 at an average dose of 15 ppm. Analysis was performed taking into consideration the actual market prices under Polish conditions. Omitted were depreciation costs which are dependent on the general investment outlay and the accepted depreciation period.

Taking into consideration the above factors and that the gravitational fast mixing would be used the costs are broken into five main groups:

Costs of flocculant - 63%
Service - 13%
Electric power - 10%
Sediment removal - 12%
Maintenance - 2%

Application of extended fast mixing with the use of air or mechanical agitators will increase the costs by some 10-13%, dependent on the employed equipment. Simultaneously, it would change the cost groups as follows:

Flocculant - 50%
Service - 10%
Electric power - 15-30%
Sediment removal - 10%
Maintenance - 3%

SECTION 9

PURIFICATION OF MINE WATERS WITH LARGE QUANTITIES OF DIFFICULT TO SETTLE SUSPENSIONS

As already mentioned, waters drained from the open-pit lignite mine in Turow contain largest amounts of suspensions, and are the most difficult to purify. The suspensions have a colloidal or pseudocolloidal character, high electrokinetic potential of up to -70 v, and a colloidal system with considerable stability. Periodically, particularly after a rainfall, these waters have suspended solids concentrations approaching 7000 ppm. Sedimentation tests carried out under still water conditions showed the reduction of suspensions after 7 days was not sufficient to meet discharge standards. Laboratory tests have indicated that the use of polymer as a basic coagulant did not give results as positive as was the case with the remaining lignite mines in Poland.

In the processes of gamma radiation application, although a 2-3 fold acceleration in reduction of turbidity and suspensions was obtained in these waters, the required time of sedimentation was too long and thus this method was not satisfactory.

Also purification of the water by the use of a sand filtration process with or without the aid of polyelectrolites gave no positive results due to very short life of the filter. Owing however to needs of the environment protection further research is needed on these waters.

These waters were investigated in a separate research study carried out by the Institute of Environment Protection Engineering in Wroclaw Technical University in the years 1976-1977[90].

As appeared from laboratory investigations carried out in 1975, the most effective method of reduction of suspension and turbidity in waters of the Turow mine was shown to be the classical coagulation with application of conventional coagulating substances such as lime, aluminum sulfate and iron sulfate.

In the framework of this report a short characterization of the methodology and of acquired results of these investigations and a suggestion for the purification of these waters will be provided.

Investigations were carried out for two cases:

-when purified water is to be used for the needs of power plant.
-when purified water will be discharged to surface flows.

In the first instance a total reduction in turbidity is required and in the second only to the level for surface waters of the I class of purity. On the basis of preliminary investigations it assumed that the technology of purification will consist of four basic processes, initial sedimentation, coagulation, sedimentation and filtration.

Process of initial sedimentation was not a subject of investigations. This process is the present technology and practiced in the reservoirs by pumping stations draining the mines. Its task is to remove the coarsest particles.

The investigations of the remaining processes were carried out on laboratory and fragmentary-technical scale.

Water during the time of performed tests had turbidity of 150-1000 ppm, 7.4-8.3 pH, iron content 0.0 to 1.25 ppm Fe, oxygen demand 15-65 ppm O_2, and suspended solids 150-1200 ppm. Used in these tests were:

Alum

$Al_2(SO_4)_3 \cdot 18\ H_2O$

Lime

$Fe_2(SO_4)_3 \cdot 9\ H_2O$

The tests were carried out on a six stand flocculator using fast mixing (80 rev/min) for 3 min, slow mixing (20 revs/min) for 20 min., and sedimentation for 20-30 minutes.

In some cases the time of fast mixing was increased to 10 minutes. Effects of coagulation were determined through measurements of turbidity, color, and oxygen demand. Inspected during the tests were also basicity and pH of purified water. Used in tests additionally were polyelectrolites but only in small doses and only as aiding means. Investigations on fragmentary-technical scale were carried out in mine working with the use of model of contact sedimentation bed.

Based upon these studies, the recommended treatment is as follows:

1) Treat with lime to a pH of 10, sedimentation and eventual filtration through a sand bed in the case where water utilization will be for drinking or for industrial purposes.

2) The coagulation with lime and iron sulfate to about pH 10, carried out together with sedimentation with or without filtration as analogical in item 1.

In both cases purified water must be subject to recarbonization processes, due to high pH, to bring its reaction to a state required dependent on further utilization.

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APPENDIX A

FLOW WAVE PLOTS

- - - - - - - Fluorescein

——— Isotope

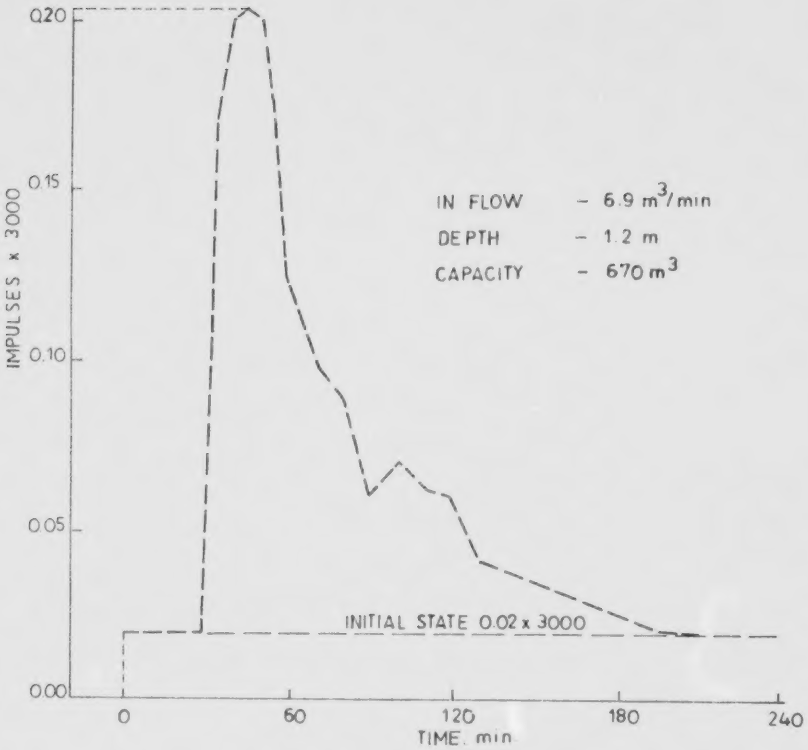


Fig. 26. Flow wave plot Number 1.

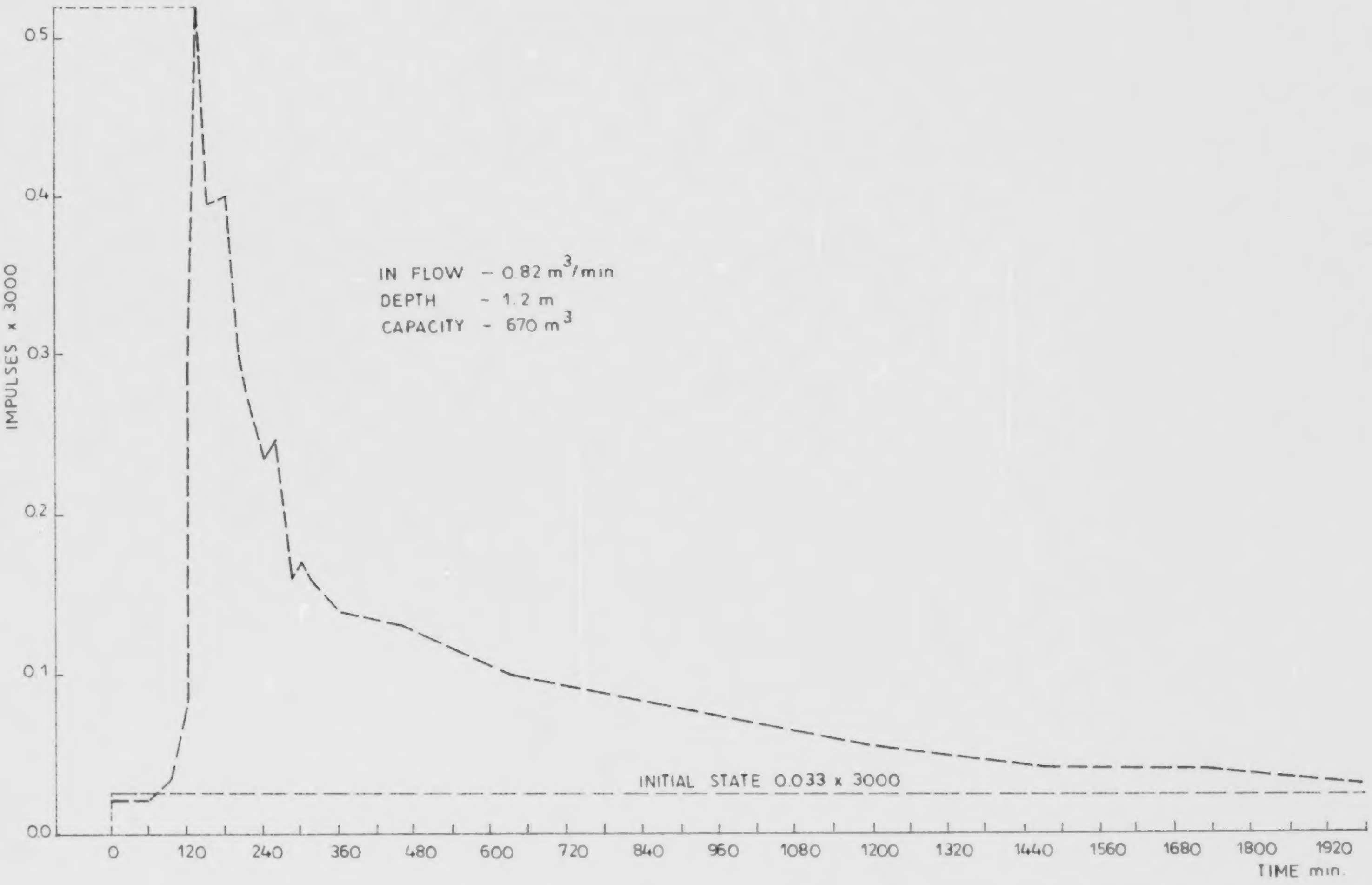


Fig. 27. Flow wave plot Number 2.

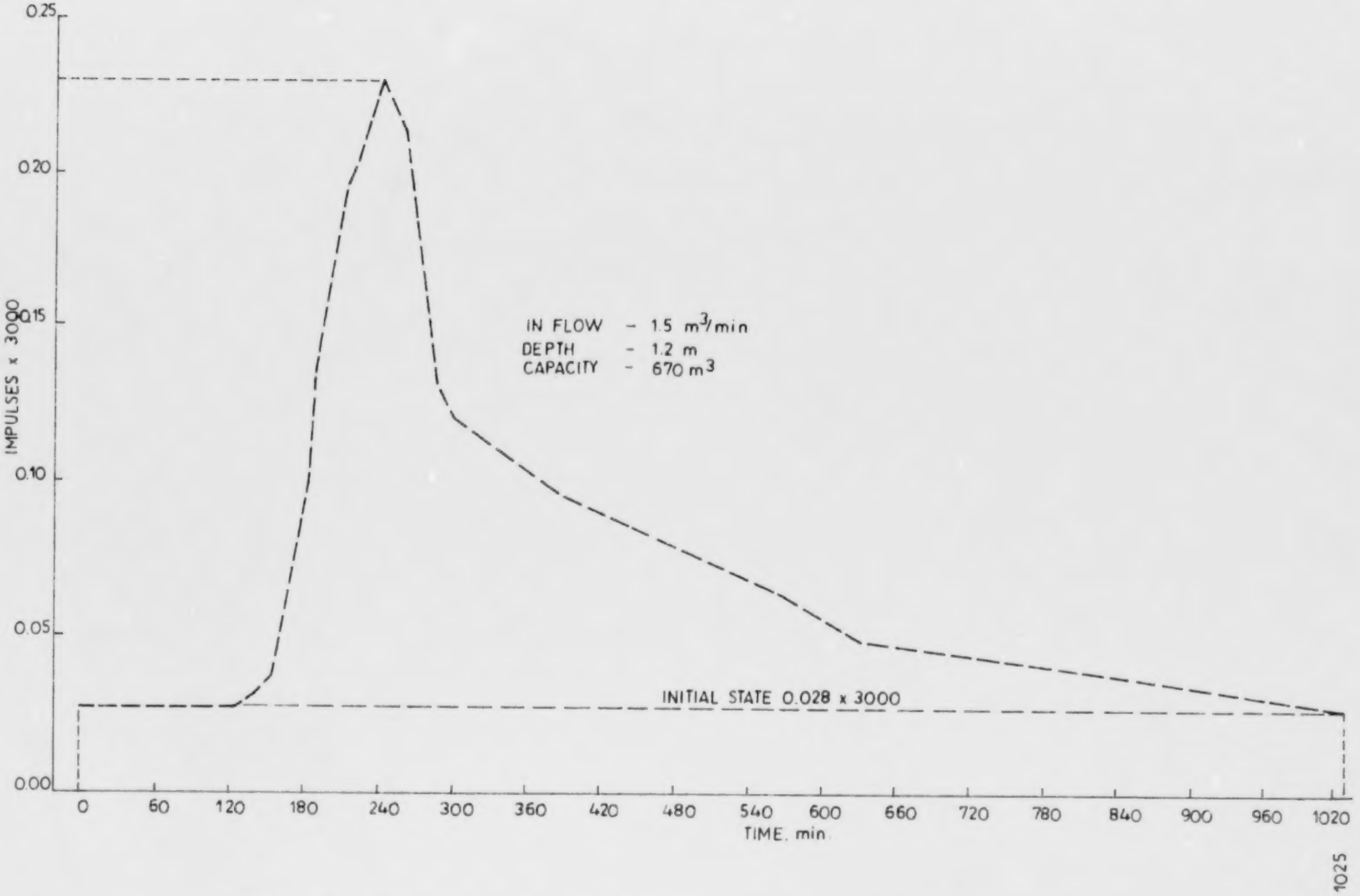


Fig. 28. Flow wave plot Number 3.

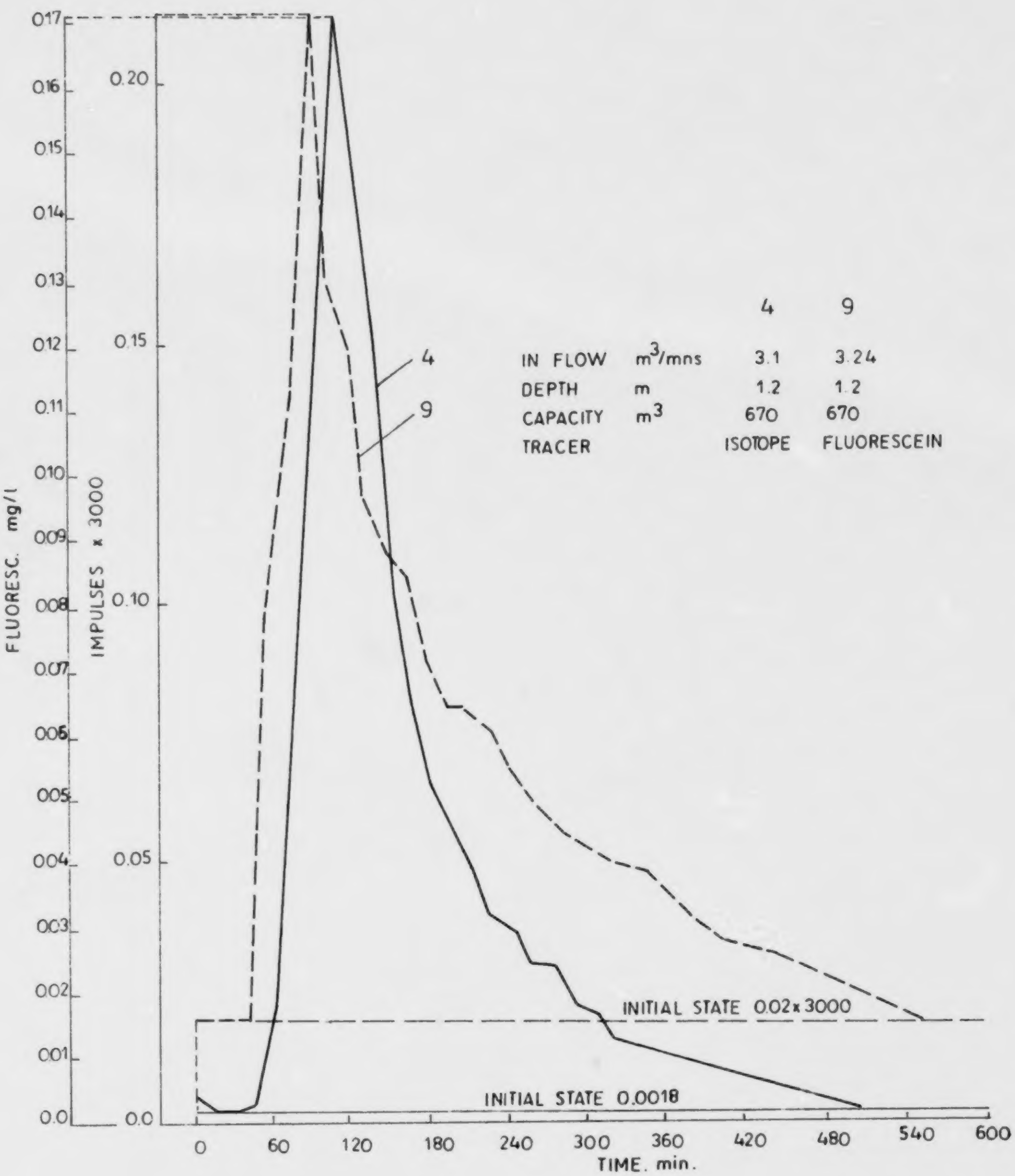


Fig. 29. Flow wave plots Number 4 and 9.

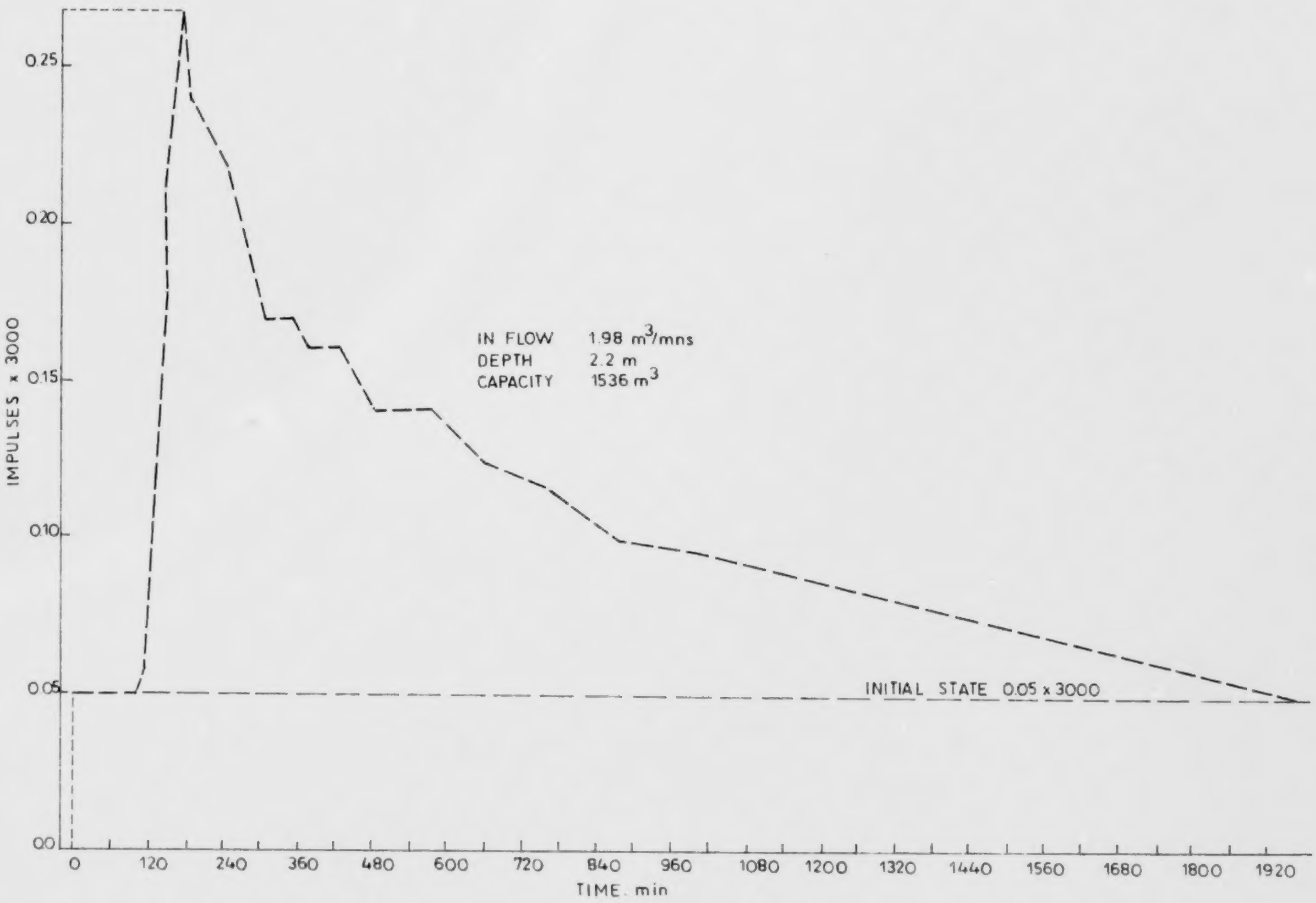


Fig. 30. Flow wave plot Number 5.

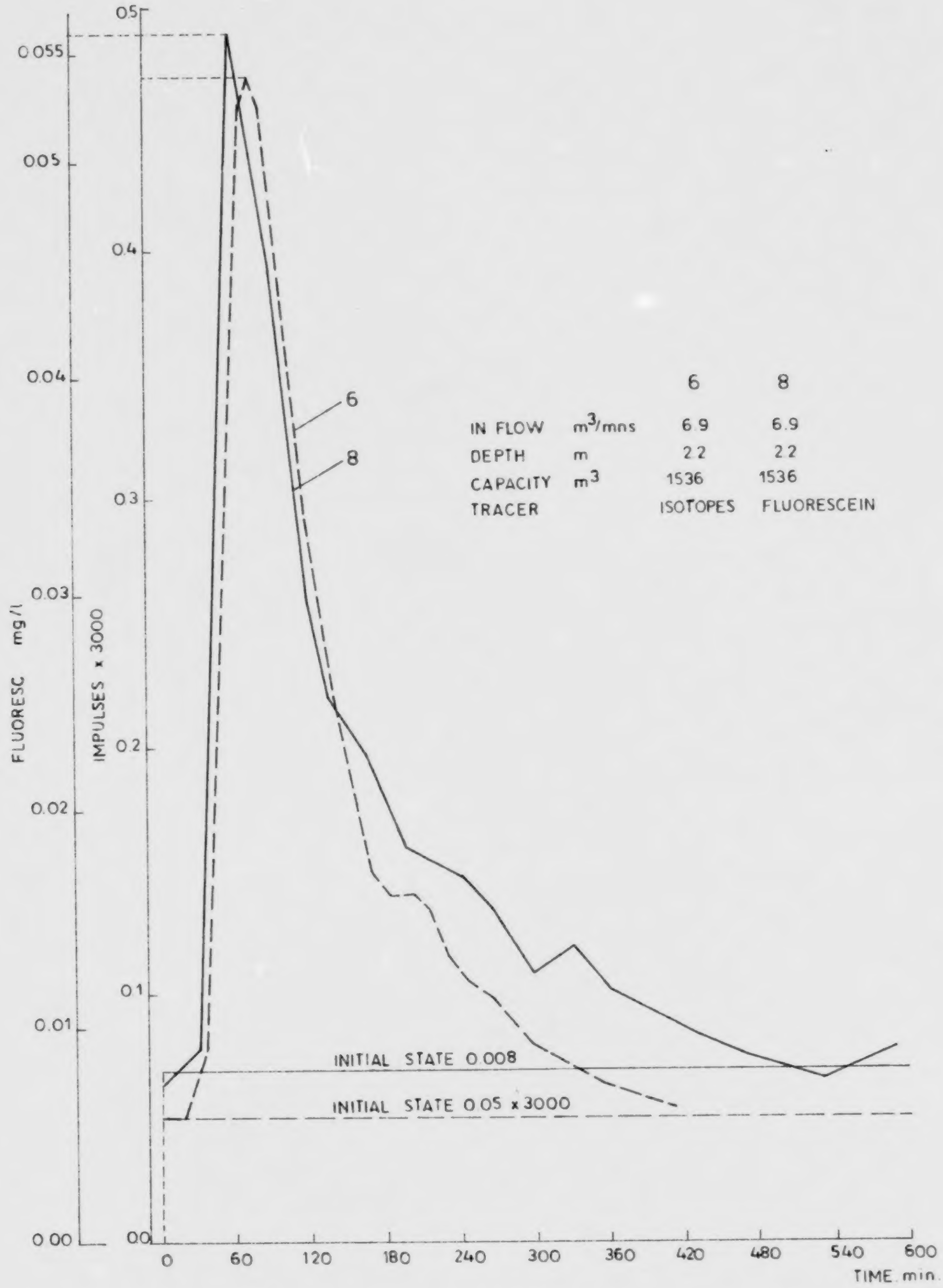


Fig. 31. Flow wave plots Number 6 and 8.

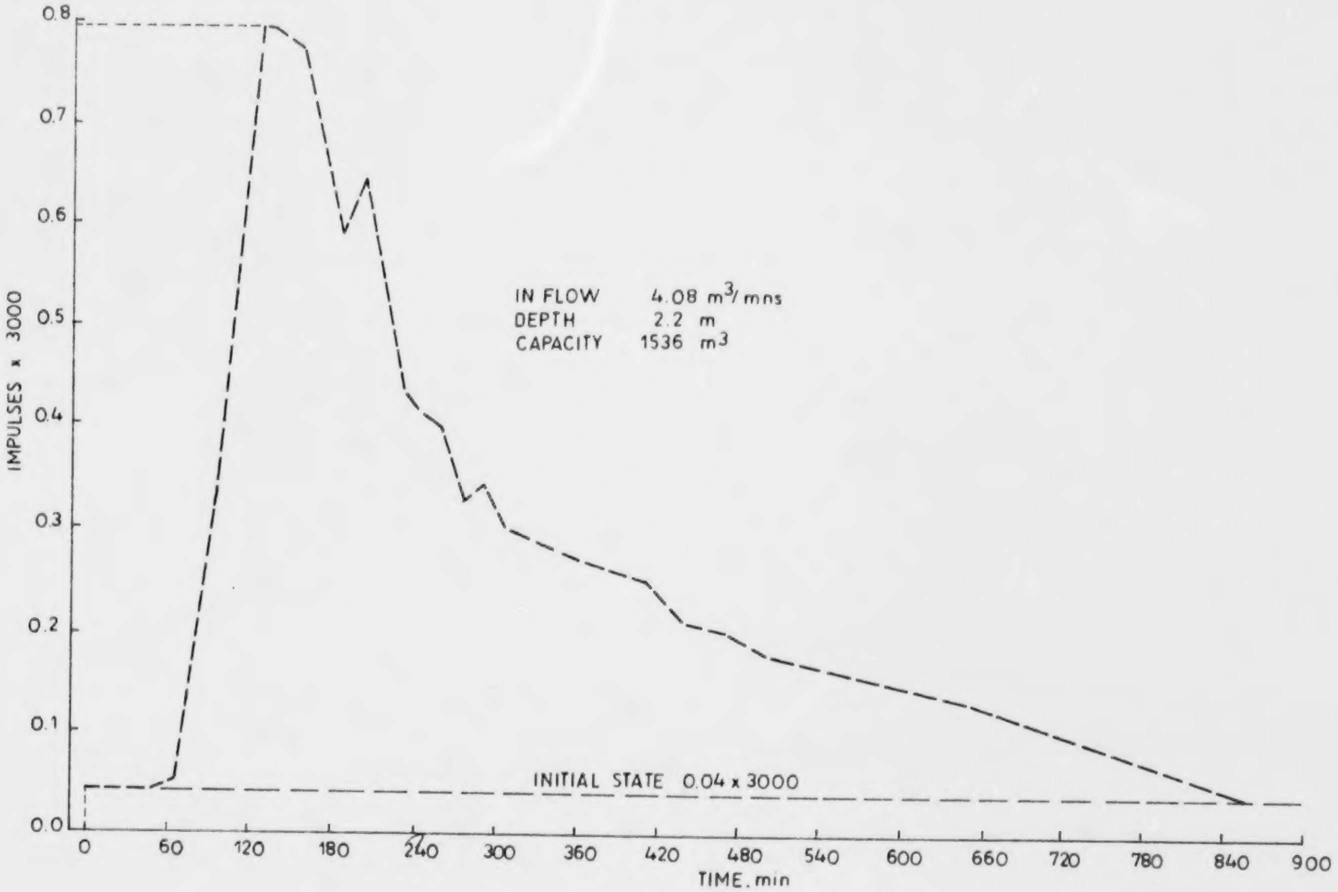
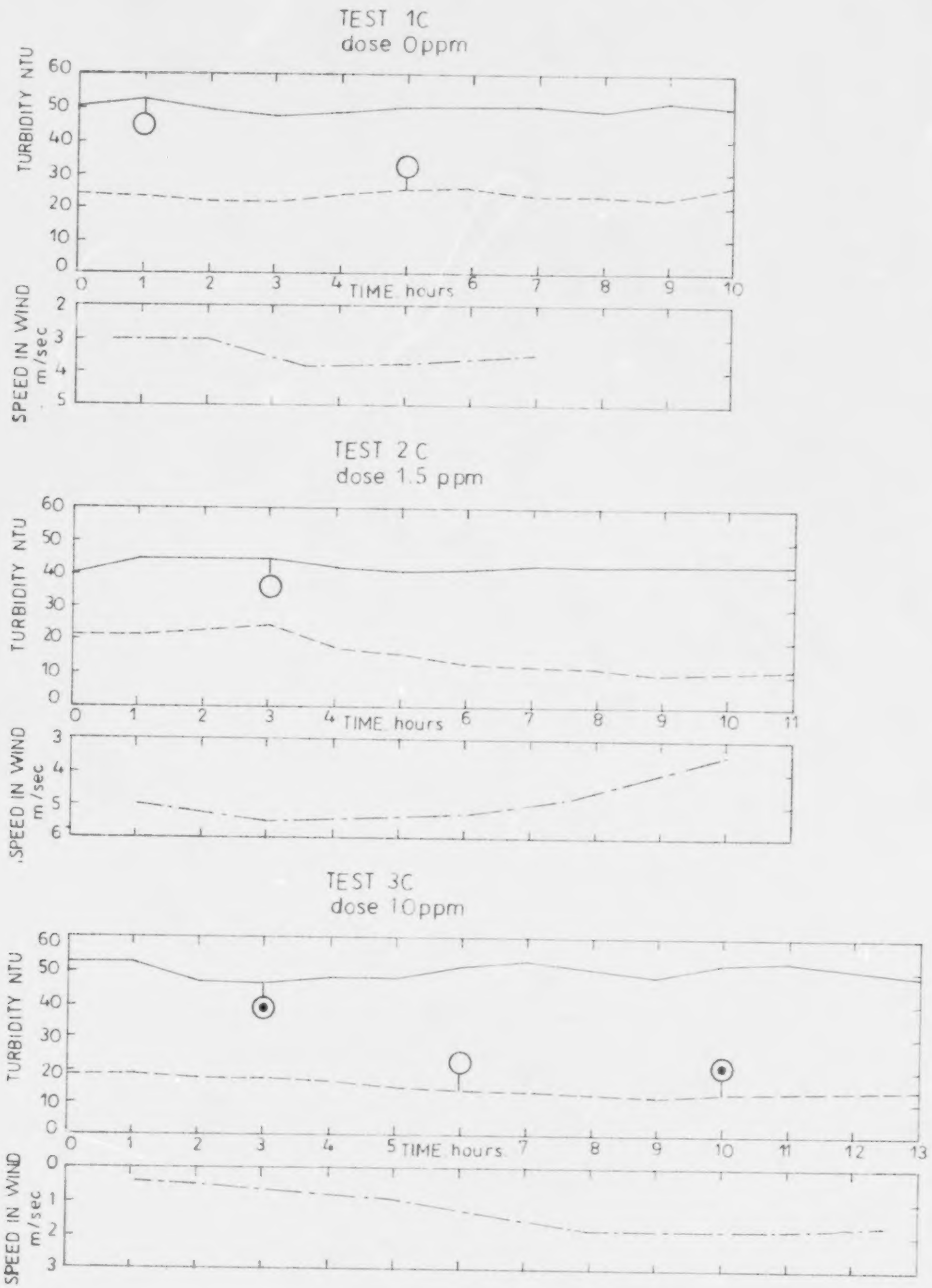


Fig. 32. Flow wave plot Number 7.

APPENDIX B

PLOTS OF RESULTS OF TESTS WITH CALGON M-502

———————	inflow
- - - - - - - - - - -	outflow
—·—·—·—	speed of wind
○	samples for shortened analysis
⊙	samples for full analysis


TEST 1C
dose 0ppm

TEST 2C
dose 1.5 ppm

TEST 3C
dose 10ppm

Fig. 33. Calgon M502 Results - Test 1c, 2c and 3c.

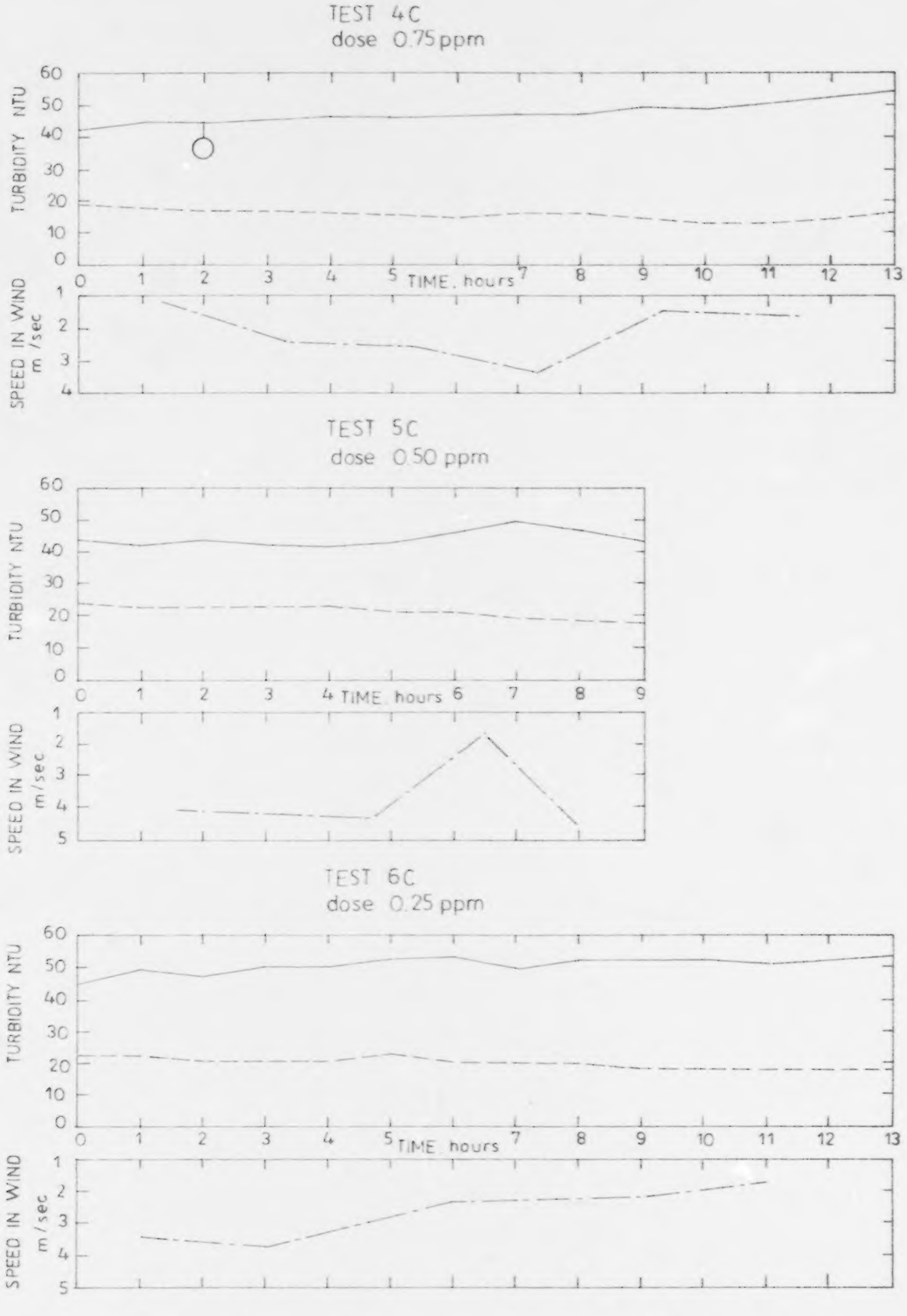


Fig. 34. Calgon M502 Results - Test 4c, 5c and 6c.

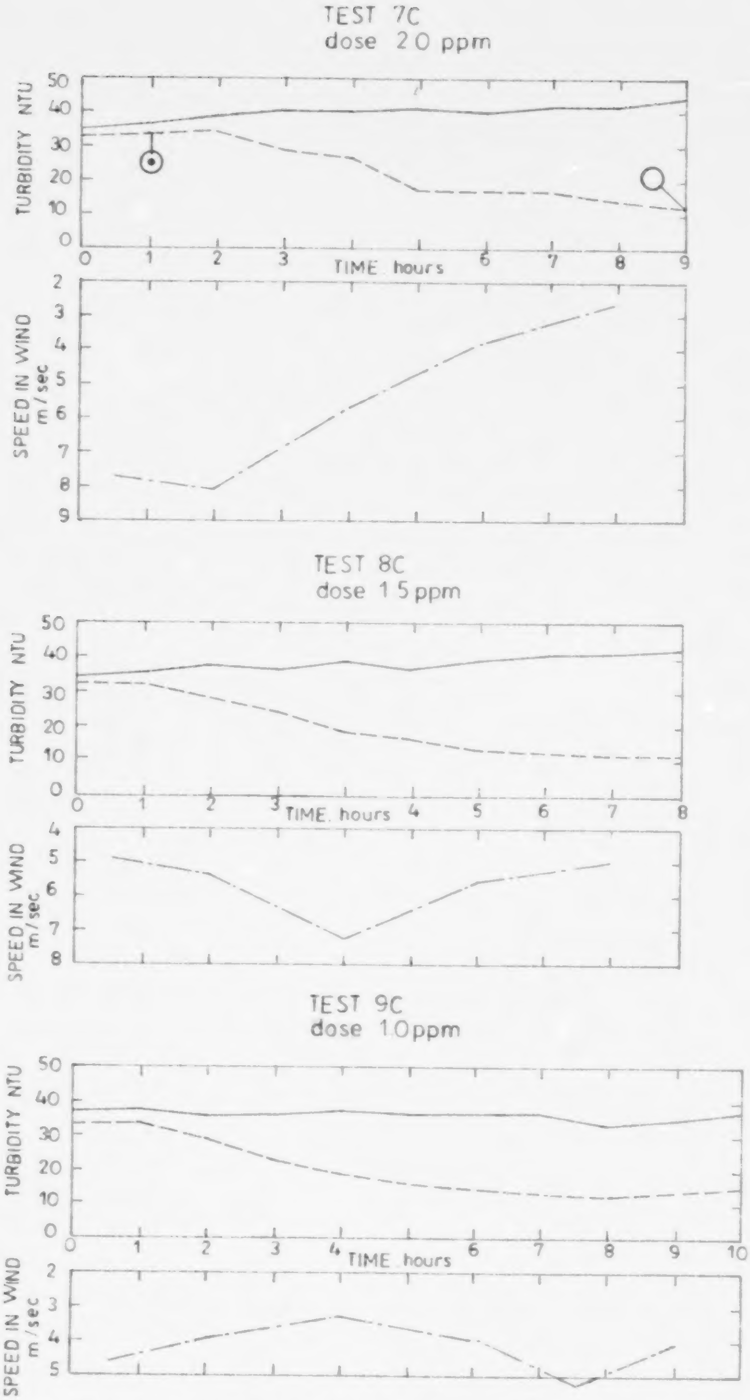
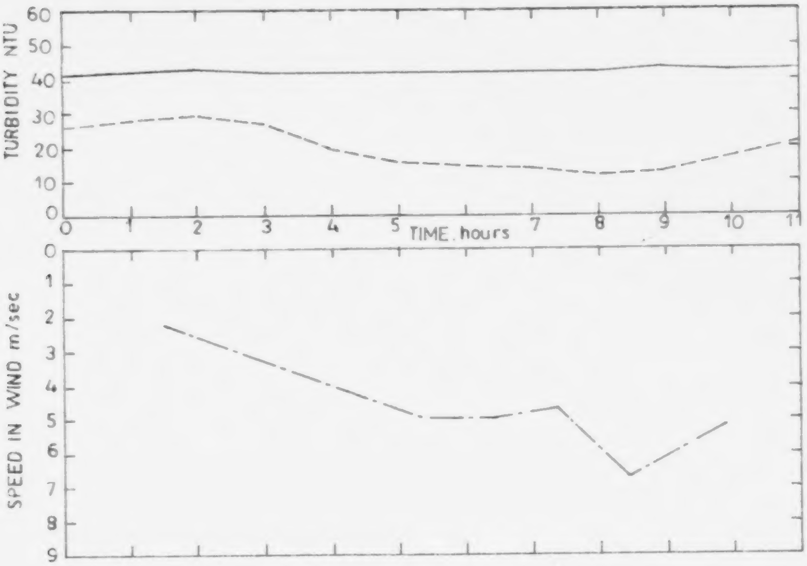


Fig. 35. Calgon M502 Results - Test 7c, 8c and 9c.

TEST 10C

dose 0.75 ppm



TEST 11C

dose 0.5 ppm

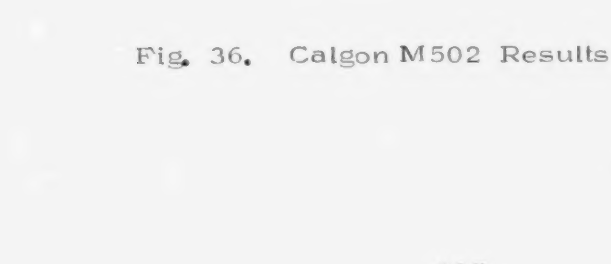


Fig. 36. Calgon M502 Results - Tests 10c and 11c.

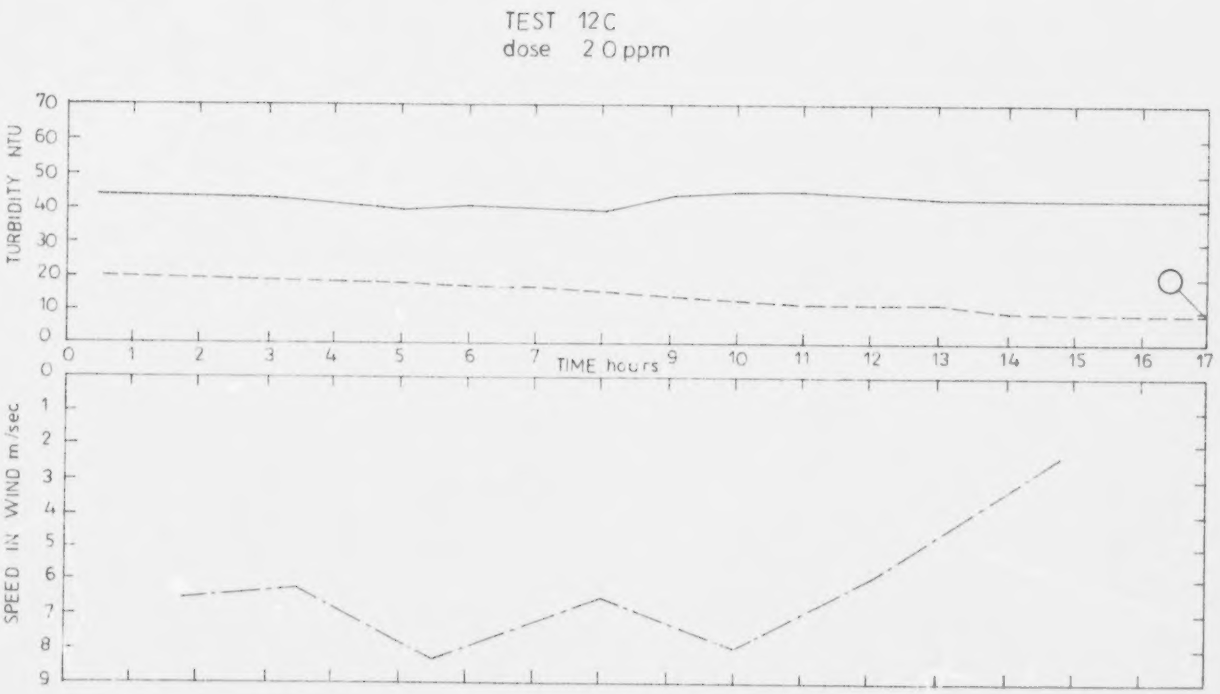


Fig. 37. Calgon M 502 Results - Test 12c.

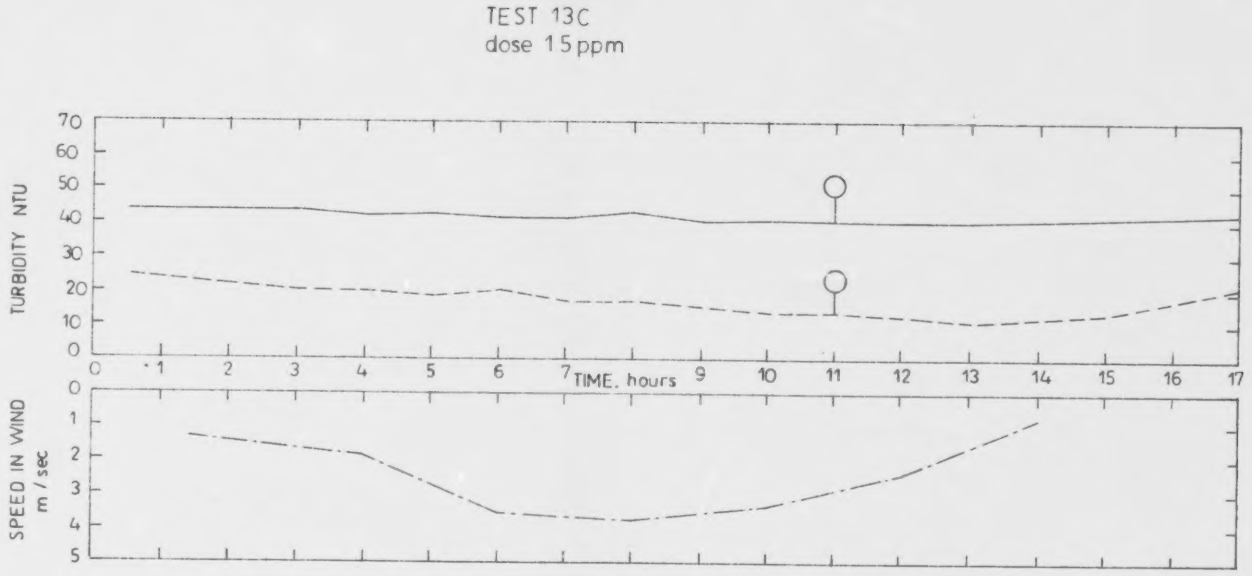
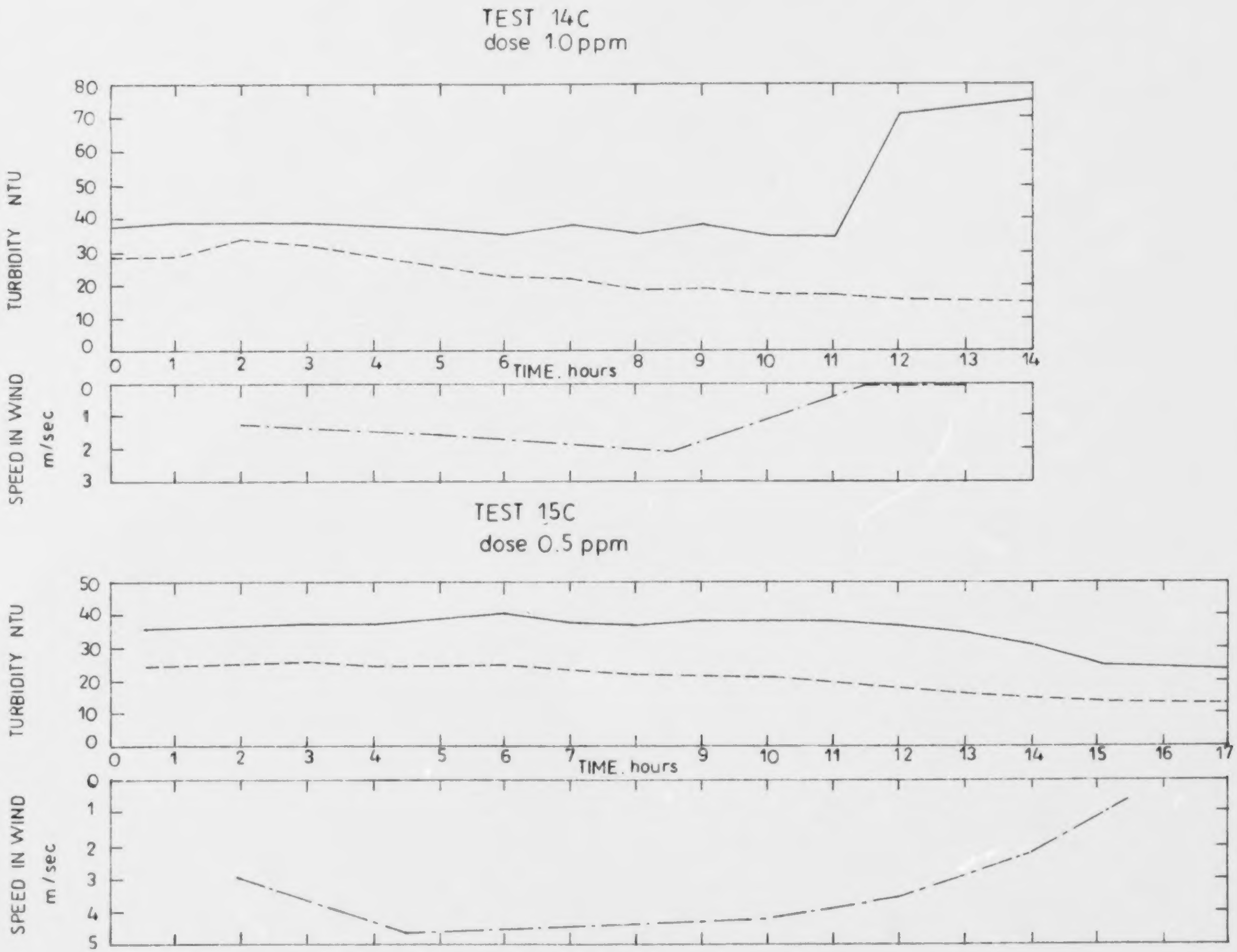


Fig. 38. Calgon M 502 Results - Test 13c.



TEST 14C
dose 10 ppm

TEST 15C
dose 0.5 ppm

Fig. 39. Calgon M 502 Results - Test 14c and 15c.

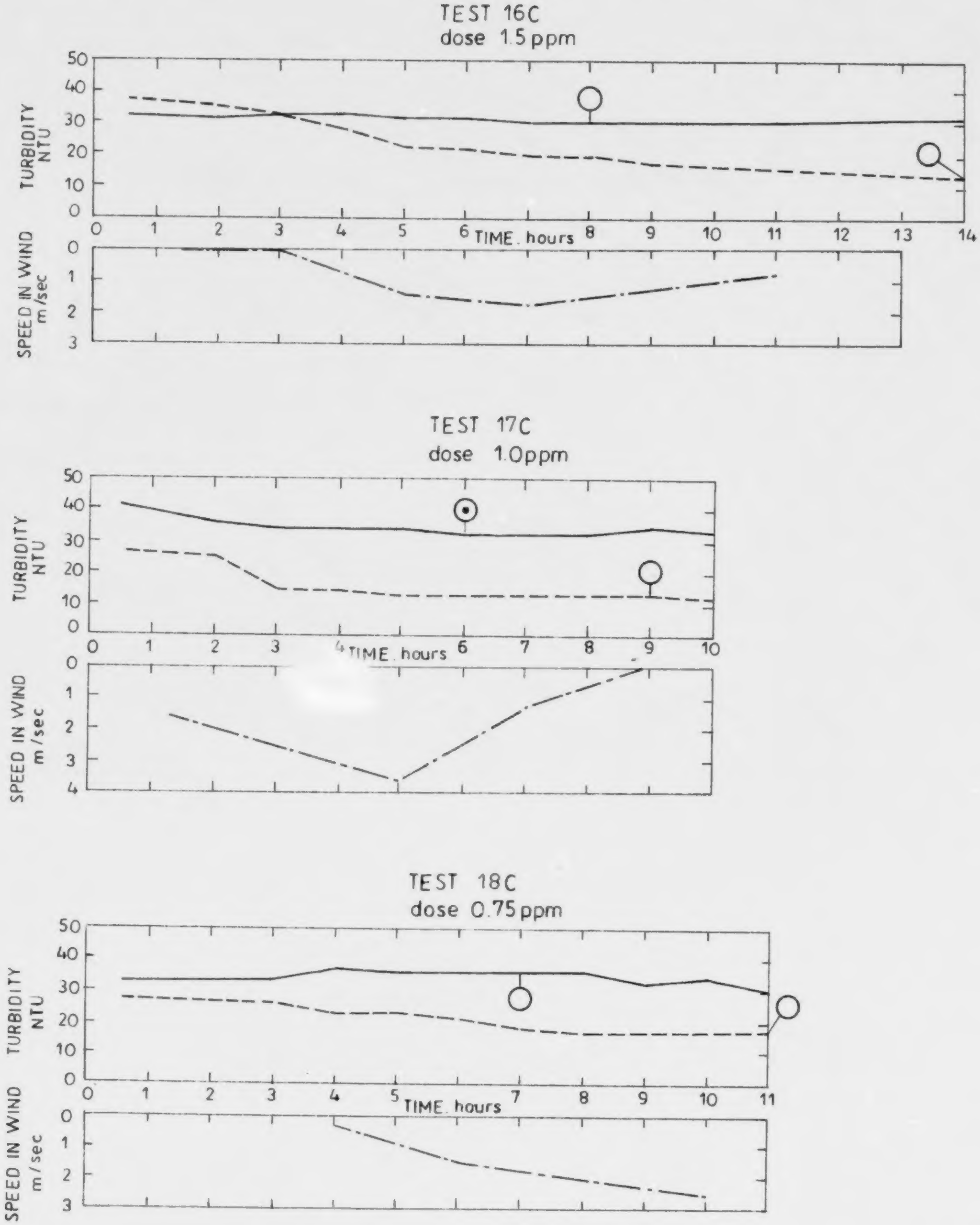
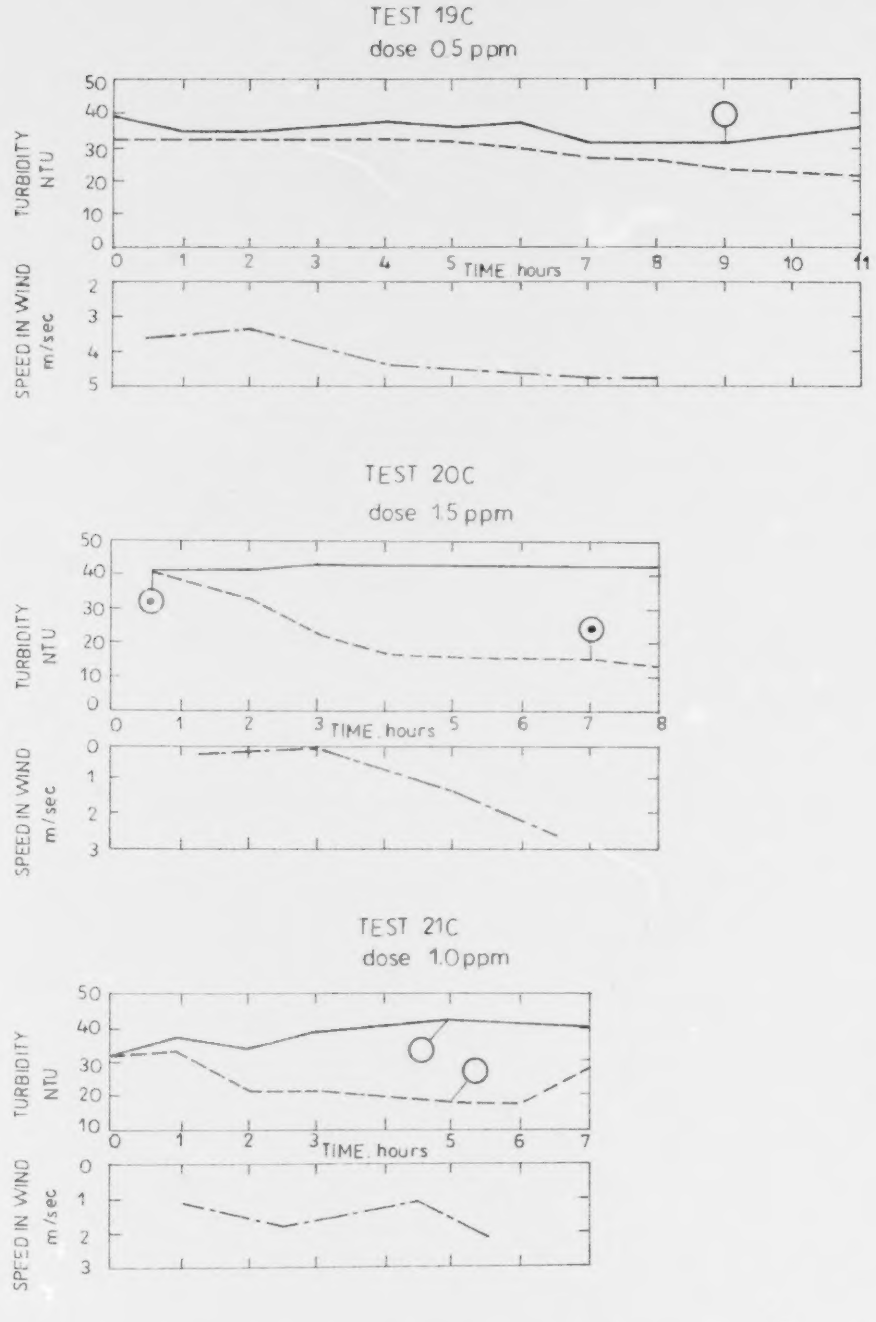


Fig. 40. Calgon M 502 Results - Test 16c, 17c and 18c.



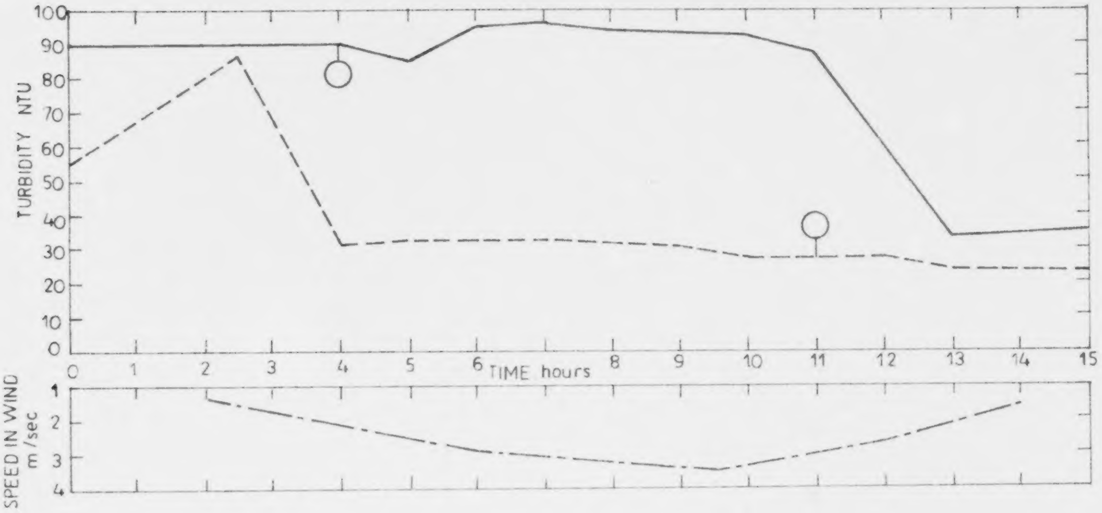
TEST 19C
dose 0.5 ppm

TEST 20C
dose 1.5 ppm

TEST 21C
dose 1.0 ppm

Fig. 41. Calgon M 502 Results - Test 19c, 20c and 21c.

TEST 22C
dose 0.75 ppm



TEST 23C
dose 0.5 ppm

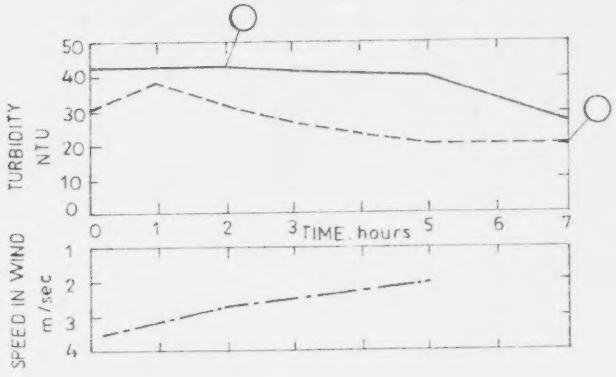
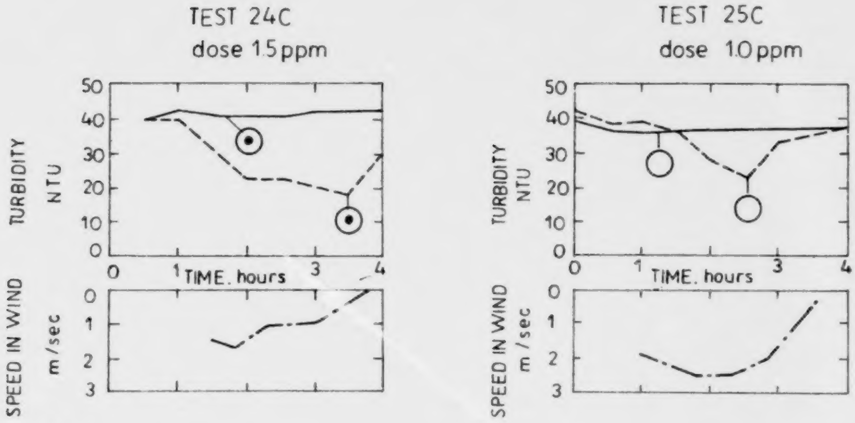
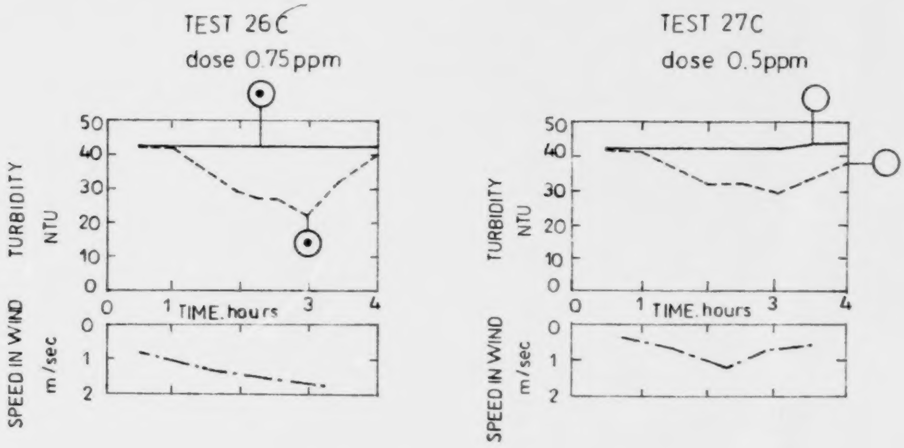


Fig. 42. Calgon M 502 Results - Test 22c and 23c.



TEST 24C
dose 1.5 ppm

TEST 25C
dose 1.0 ppm

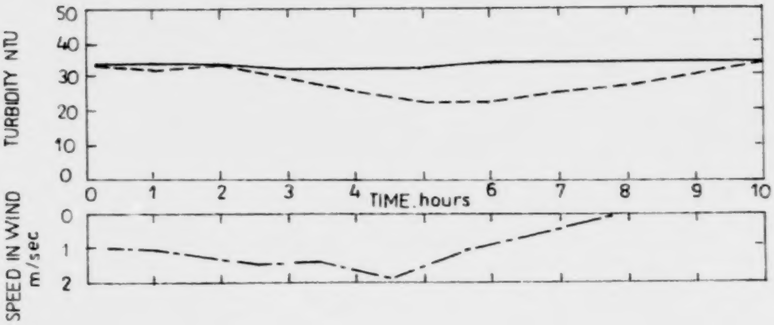


TEST 26C
dose 0.75 ppm

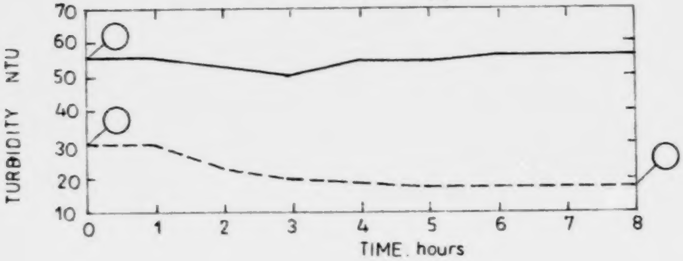
TEST 27C
dose 0.5 ppm

Fig. 43. Calgon M 502 Results - Tests 24c, 25c, 26c, and 27c.

TEST 28C
dose 1.0 ppm



TEST 29C
dose 4.0 ppm



TEST 30C
dose 4.0 ppm

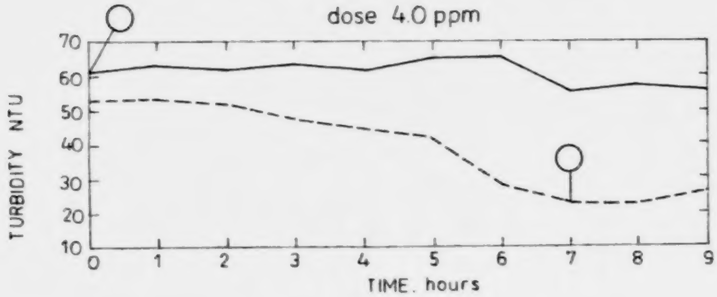
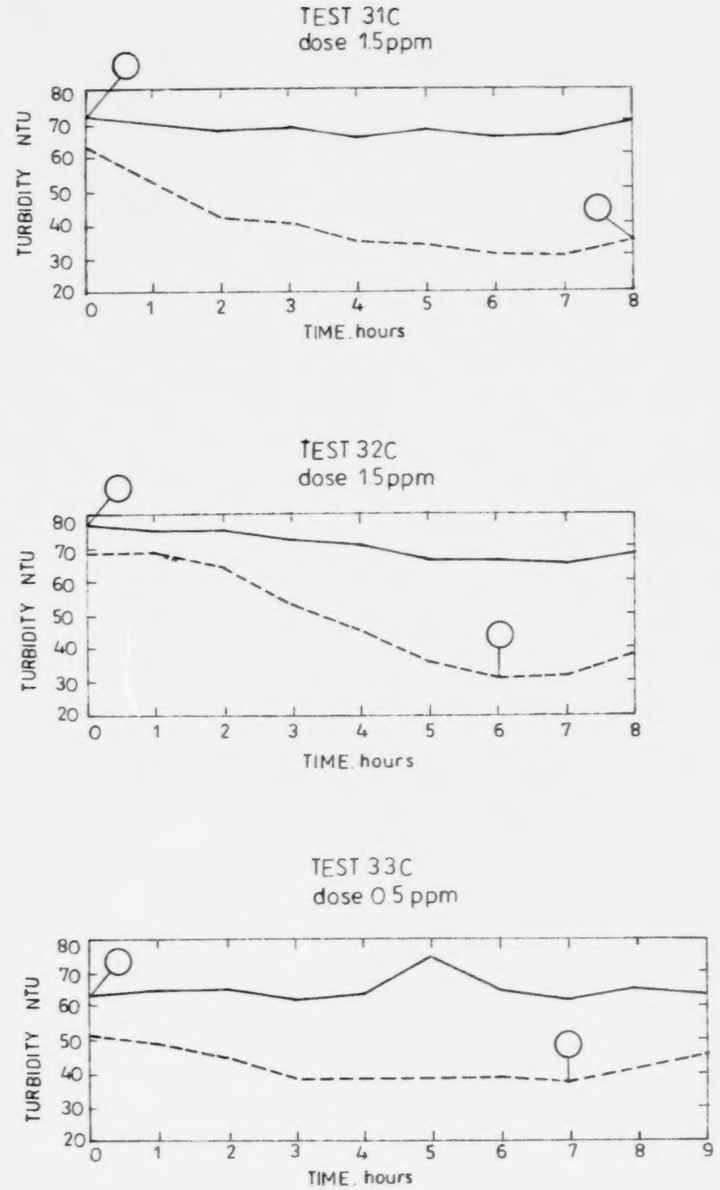


Fig. 44. Calgon M502 Results - Tests 28c, 29c, and 30c.

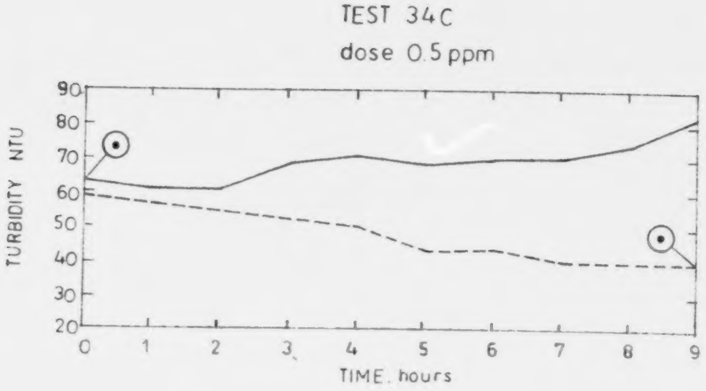


TEST 31C
dose 1.5ppm

TEST 32C
dose 1.5ppm

TEST 33C
dose 0.5 ppm

Test. 45. Calgon M 502 Results - Tests 31c, 32c, and 33c.



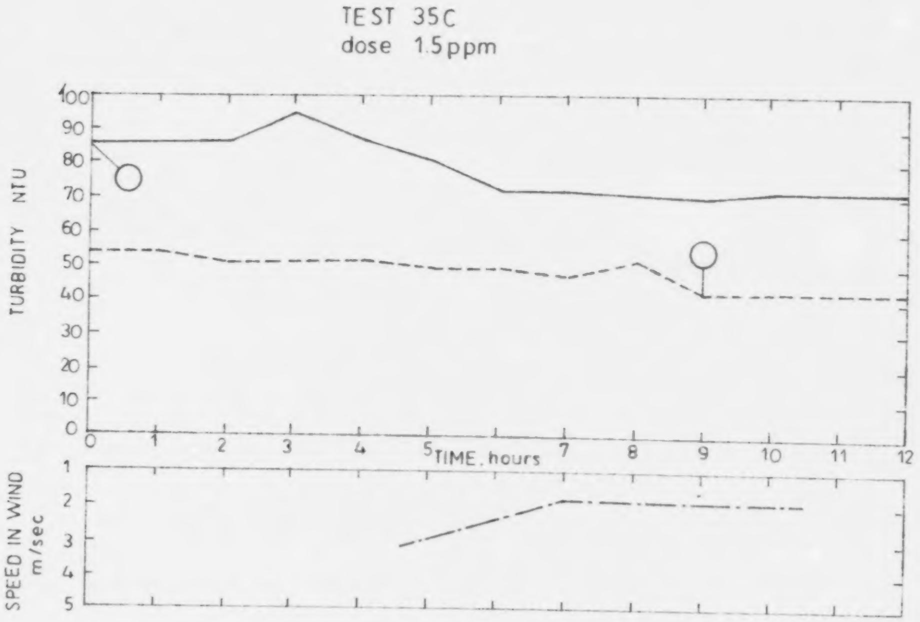


Fig. 46. Calgon M 502 Results - Test 34c and 35c.

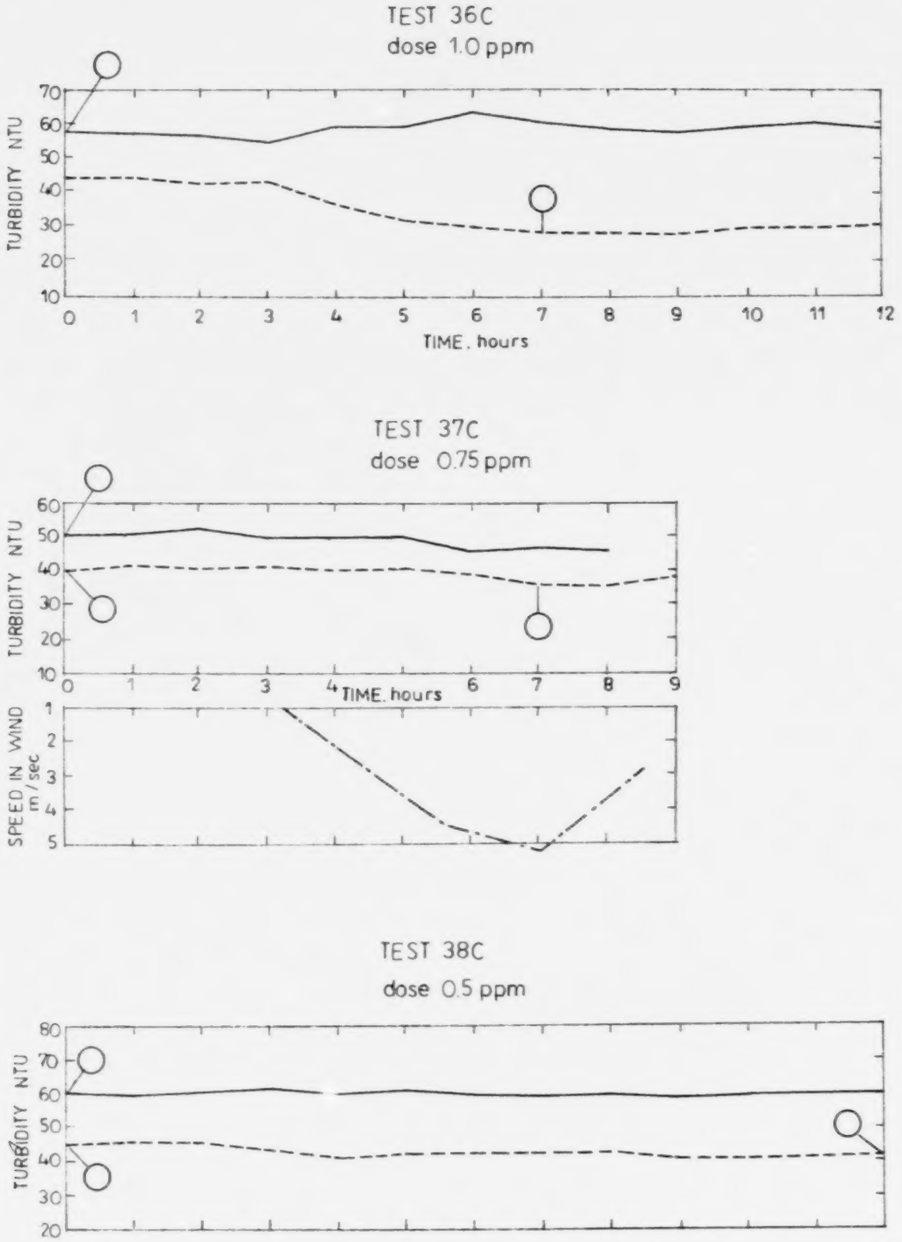


Fig. 47. Calgon M 502 Results - Test 36c, 37c and 38c.

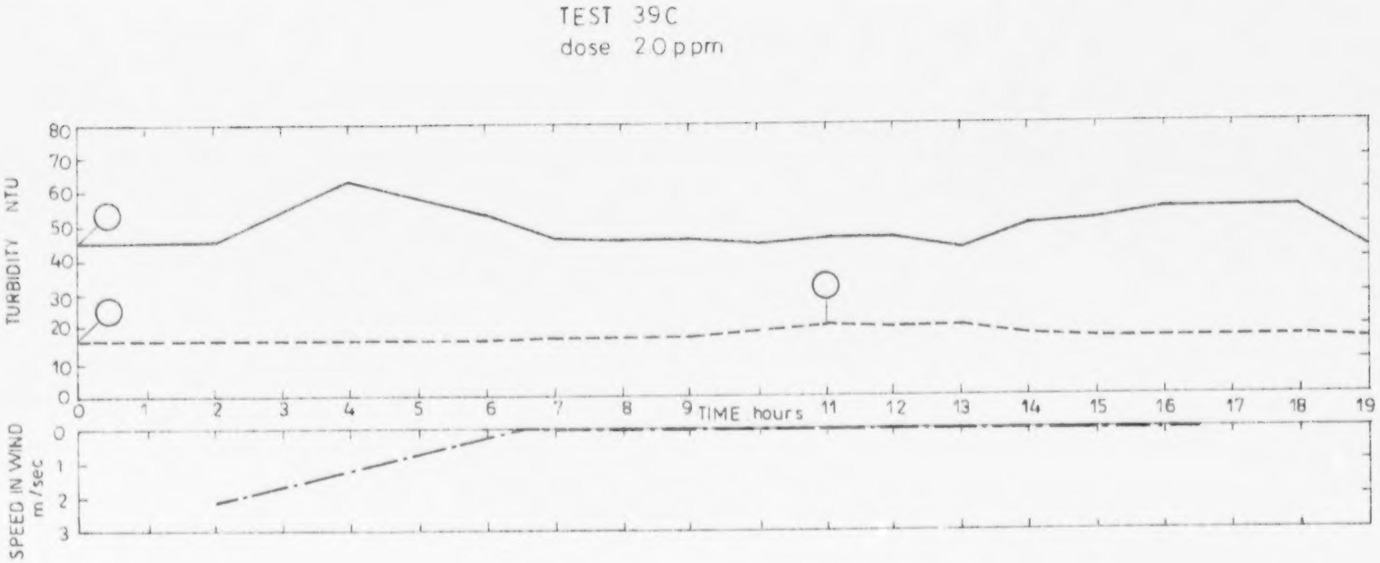


Fig. 48. Calgon M 502 Results - Test 39c.

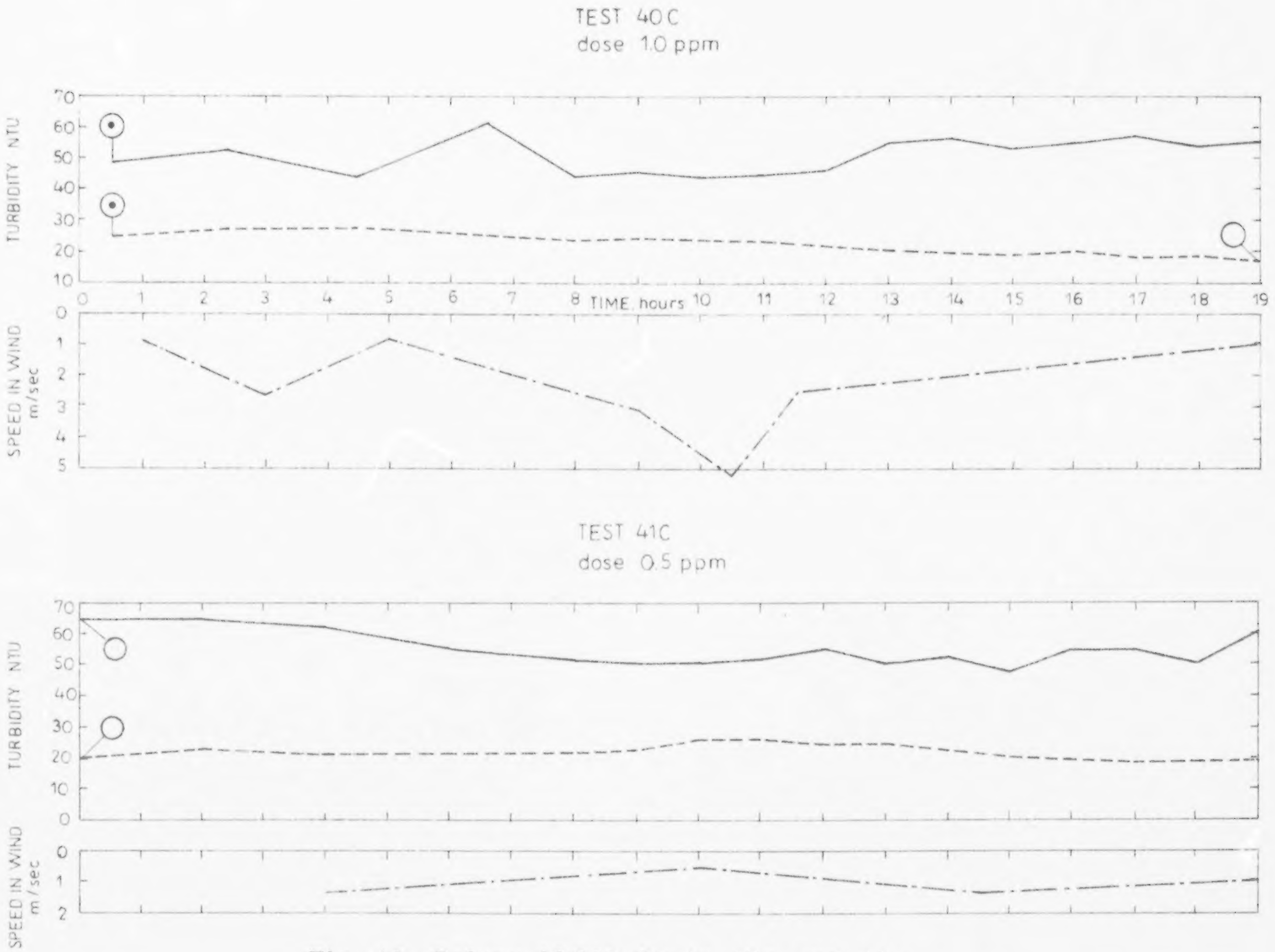


Fig. 49. Calgon M 502 Tests 40c and 41c.

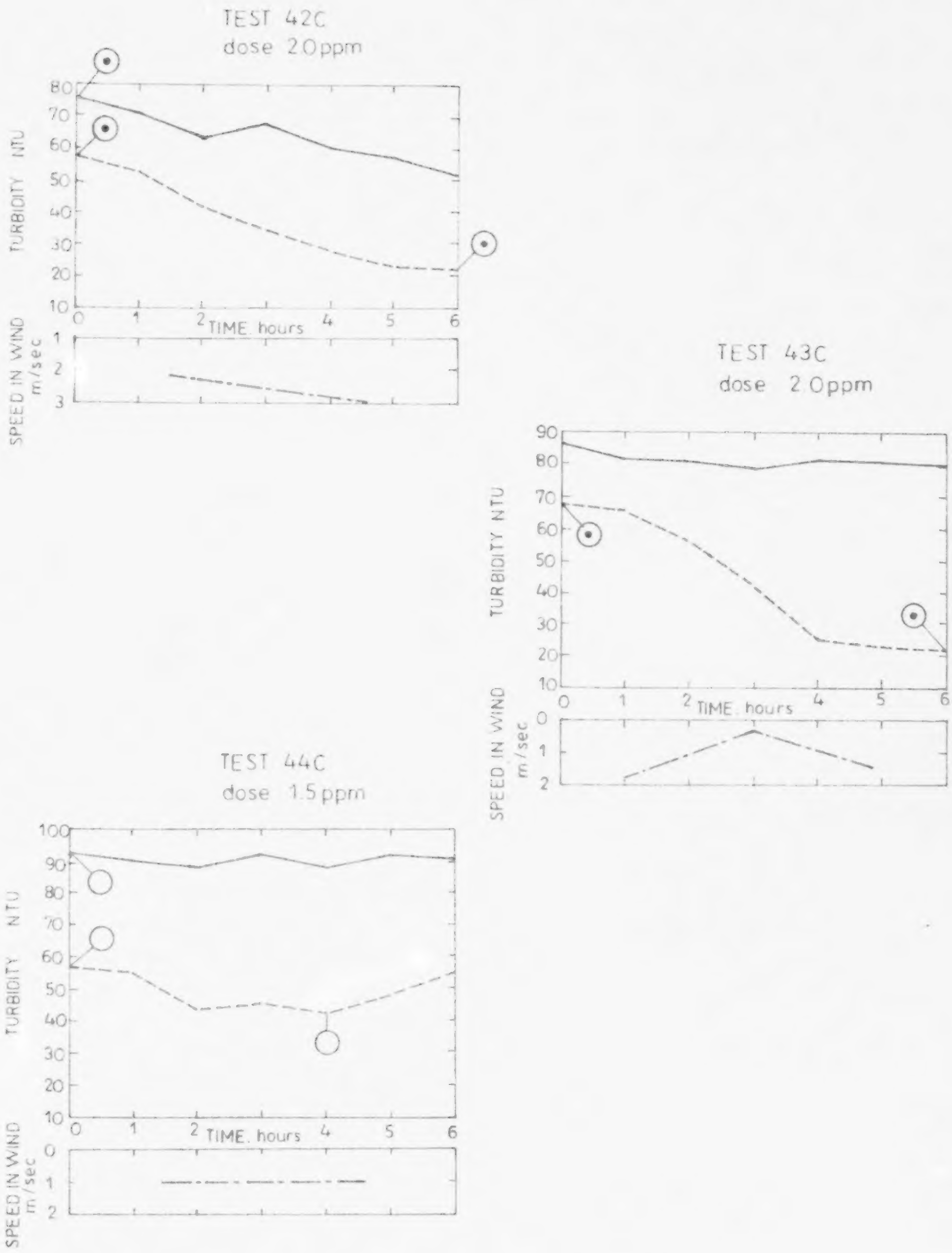


Fig. 50. Calgon M 502 Results - Test 42c, 43c, and 44c.

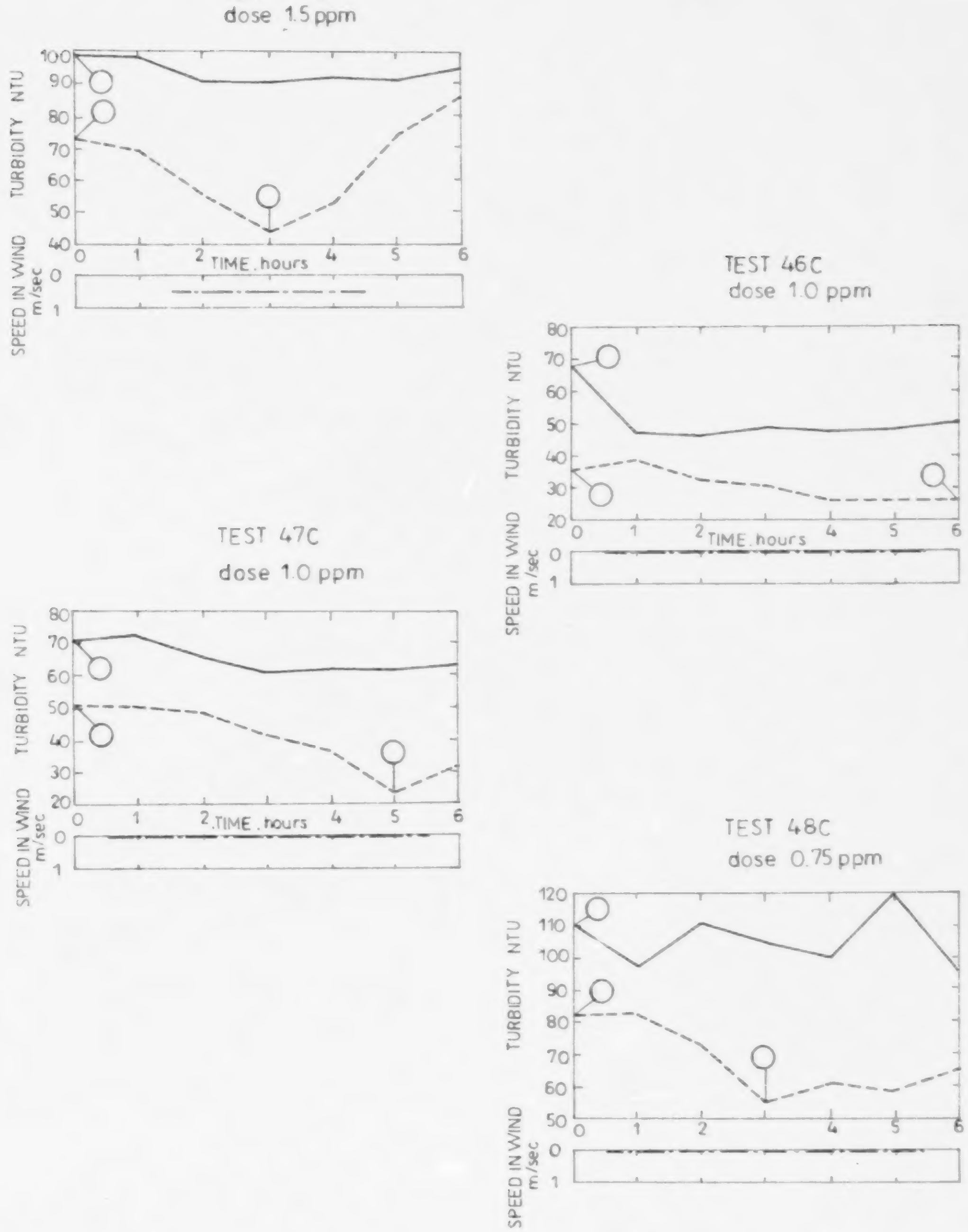


Fig. 51. Calgon M 502 Results - Test 45c, 46c, 47c and 48c.

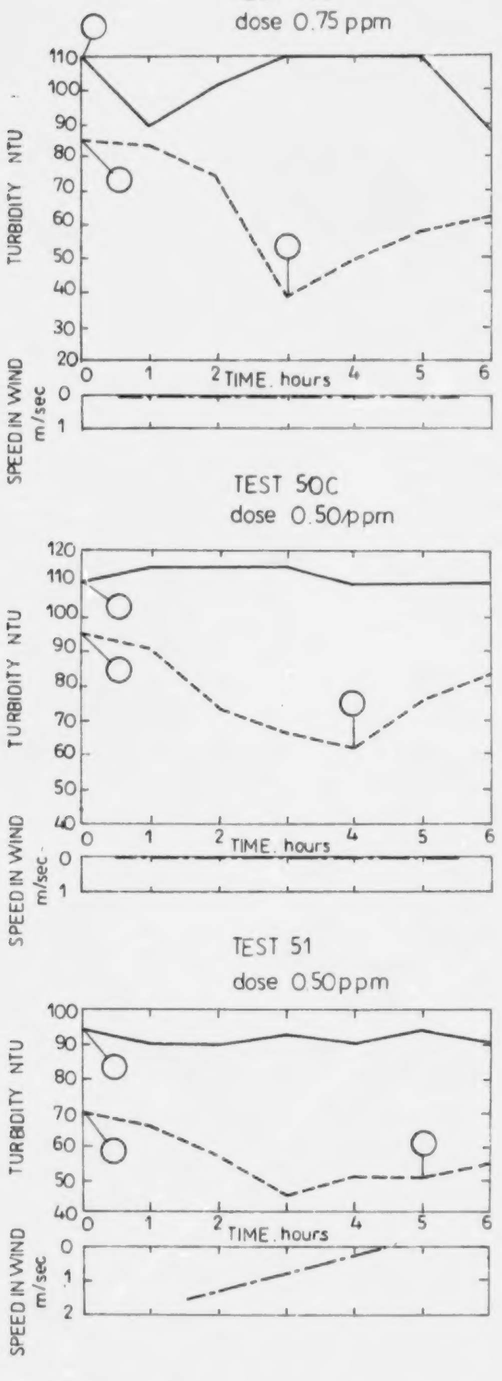


Fig. 52. Calgon M 502 Results - Tests 49c, 50c and 51c.

APPENDIX C

PLOTS OF RESULTS OF TESTS WITH ROKRYSOL WF-5

———————— inflow

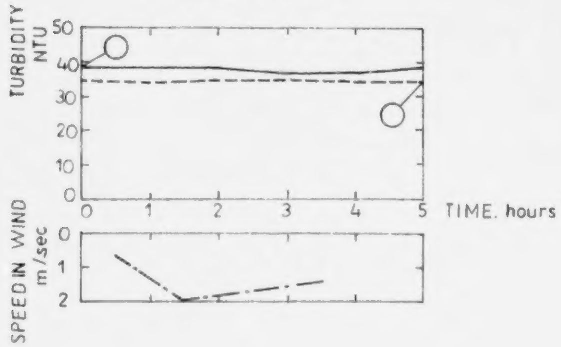
- - - - - - - - outflow

—·———·———·— speed of wind

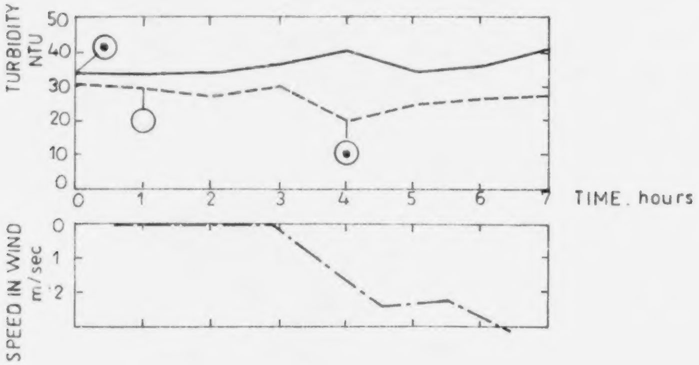
⚲ samples for shortened analysis

⊙ samples for full analysis

TEST 1R
dose 0 ppm



TEST 2R
dose 5.0ppm



TEST 3R
dose 8.2 ppm

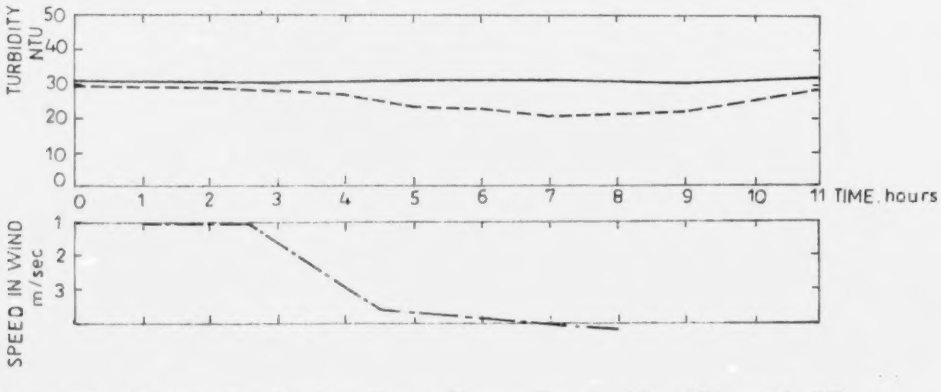


Fig. 53. Rokrysol WF-5 Results - Test 1R, 2R and 3R.

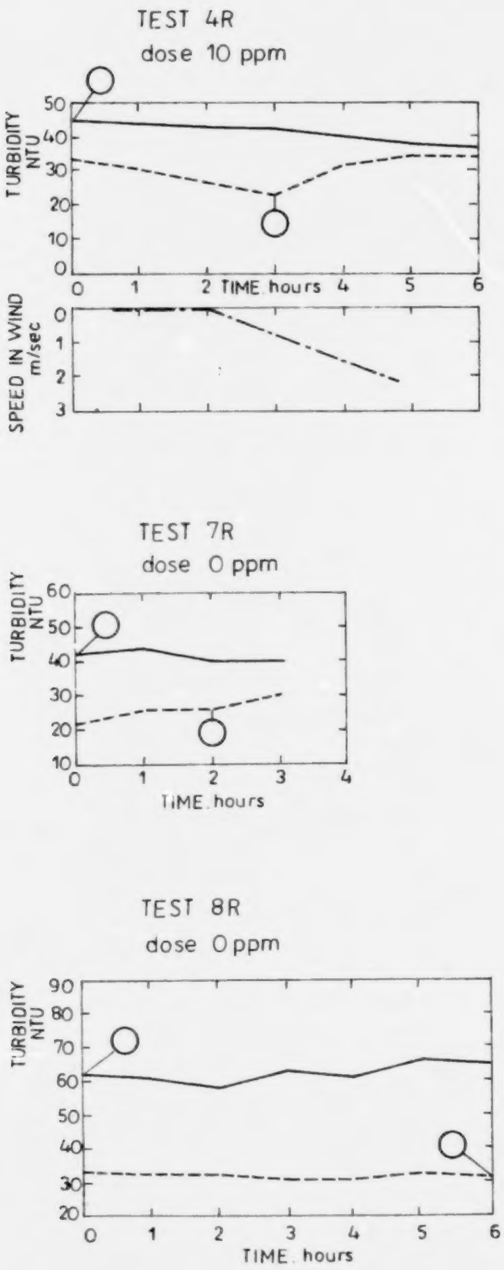
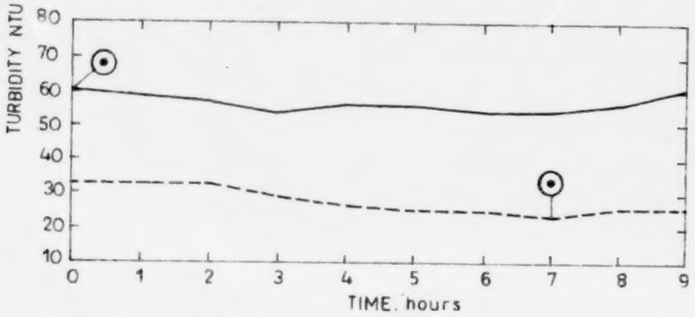
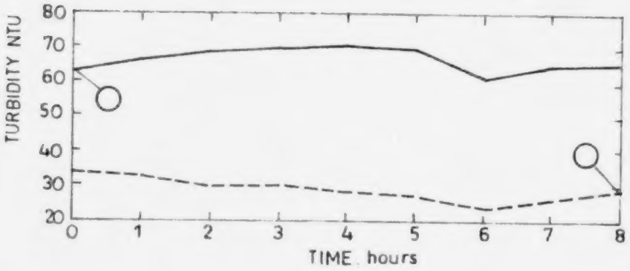


Fig. 54. Rokrysol WF-5 Results - Test 4R, 7R and 8R.

TEST 9R
dose 2 ppm



TEST 10R
dose 2ppm



TEST 11R
dose 4.2ppm

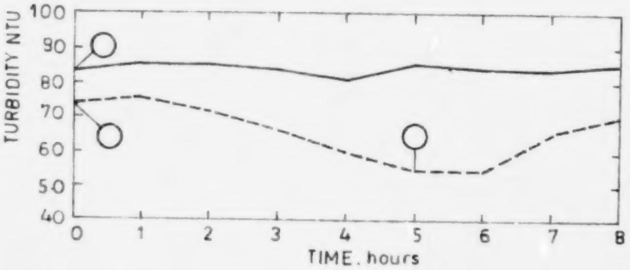


Fig. 55. Rokrysol WF-5 Results - Test 9R, 10R and 11R.

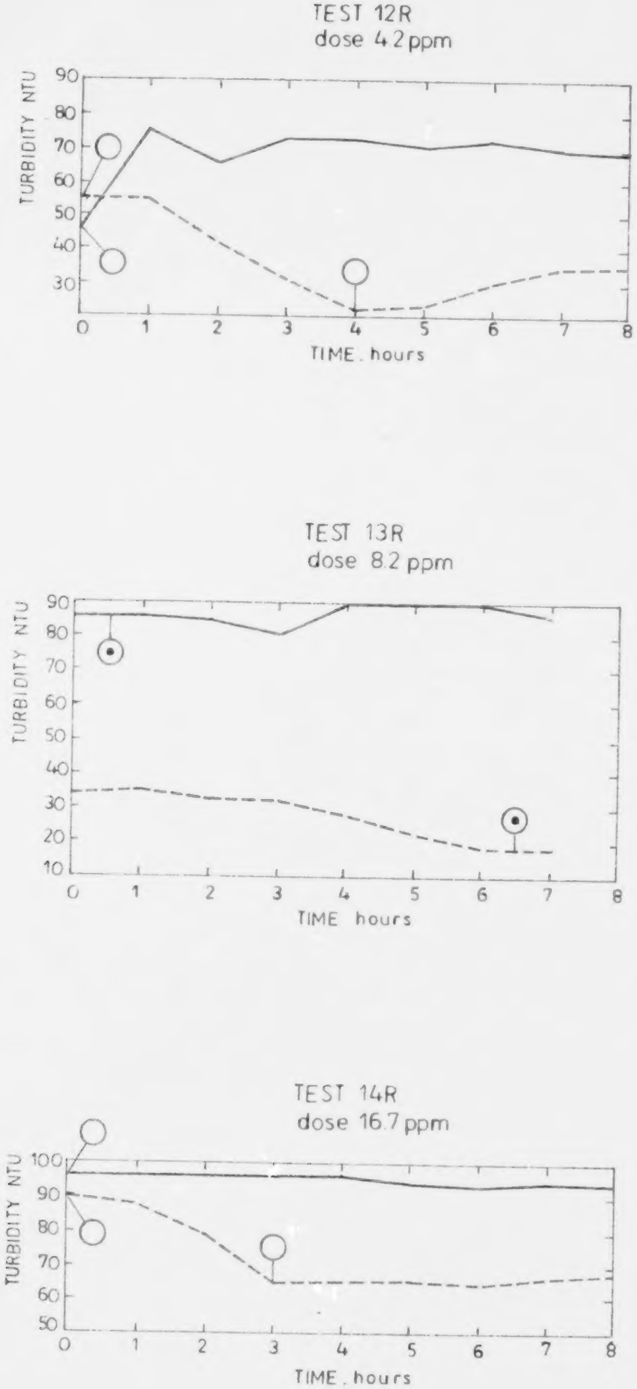
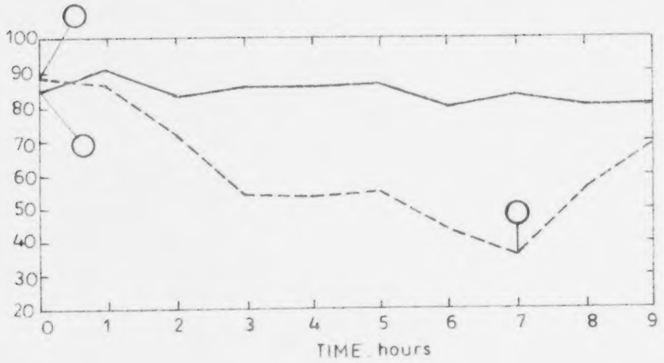


Fig. 56. Rokrysol WF-5 Results - Test 12R, 13R and 14R.

TEST 15R
dose 16.7 ppm



TEST 16R
dose 0 ppm

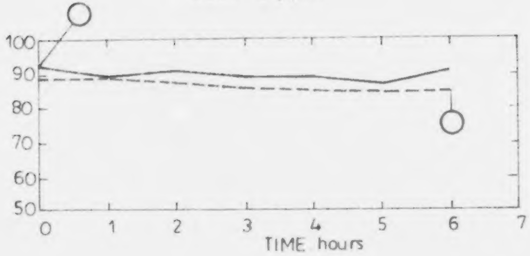


Fig. 57. Rokrysol WF-5 Results - Test 14R and 16R.

APPENDIX D

TUROW II MINE WATER

I SERIES

Tab. 22

Coagulant	Nr	Dose (ppm)	pH before coagul.	pH after coagul.	Basicity (mv)	Color (ppm)	Turbidity (ppm)	C.O.D. (ppm) O_2	Poten-tial ζ mv	Hardnes (° hard)	Remarks
1	2	3	4	5	6	7	8	9	10	11	12
Temp. 23°C CALGON M-502	0	0,0	7.8	–	3,8	20	300	15,0	-23.0	20,5	1. Mine waters after 2hrs of sedimentation. 2. C.O.D determined in filtered off samples.
	1	10	5.0	5.2	0,4	0 - 5	5-10	6.2	-18,5	21.0	
	2	10	6.0	6,2	1.3	0 - 5	5-10	6,3	-20.0	22,0	
	3	10	7.8	8,1	3.6	0 - 5	3-5	5,3	-22,0	17.2	
	4	10	9.0	9,1	4.3	0 - 5	3 - 5	5.8	-23,0	15.3	
	5	10	10,0	9,6	3,7	0 - 5	10	6,4	-27.5	11,4	
	6	10	11,0	10,6	4,3	0 - 5	10	6,8	-22,5	11,4	

Tab. 23

6.5°C CALGON M-502	0	0,0	7,8	–	3,8	20	300	20,0	-23,0	20,5	Points from 1, 2 as above
	1	10	5,0	6.0	0,4	< 5	5	6,4	-27,0	20,0	
	2	10	6.0	6,3	1,3	< 5	10	6,4		20.5	
	3	10	7,8	7.8	3,6	< 5	15	6,4	-20,0	19.7	
	4	10	9,0	9,0	4,1	< 5	15	5,2		20,0	
	5	10	10,0	9,8	3.8	< 5	< 3	6,4		15,1	
	6	10	11,0	10,8	4,6	< 5	< 3	8.8	-30,5	12.0	

Tab. 24

3°C CALGON M-502	0	0,0	7.8	–	3.8	30	300	20,0	-23.0	20,5	Points from 1, 2 as above 3. Color designated with SPECOL
	1	10	5.0	5,2	0,3	30	10	5,4	-23.5	22.8	
	2	10	6.0	6,1	1,5	20	20	6,6		23.2	
	3	10	7,8	7,8	4.2	24	15	7,0	-23.5	23,2	
	4	10	9,0	7.6	3,9	34	15	6,0		23,2	
	5	10	10,0	9,6	4,6	34	15	7.6	-23.5	18,0	
	6	10	10,0	10,7	4,1	24	10	7.6		12,0	

Tab. 25

1	2	3	4	5	6	7	8	9	10	12
22°C CALGON M-503	0	0,0	7.6	–	3.8	20	300	32,0	–	Points from 1, 2 as above
	1	1,0	8,0	–	3.8	<10	< 2	7,3	–	
	2	3,0	8,4	–	3.8	< 5	< 2	6.9	–	
	3	5.0	8,4	–	3,7	< 5	< 2	8,6	–	
	4	10,0	8,1	–	3,8	< 5	< 2	5,8	–	
	5	30,0	8,1	–	3,8	< 5	< 2	7,0	–	
	6	50,0	8,1	–	3,8	< 5	< 2	8,0	–	

Tab. 26

1	2	3	4	5	6	7	8	9	10	12
Temp. 22°C **CALGON M-590**	0	0.0	7,6	–	3,8	15-20	300	32.0	–	1. Mine waters after 2 hrs of sedimentation 2. C.O.D. determined in filtered off samples
	1	0,1	8.2	–	3,8	15-20	40	7.3	–	
	2	0,3	8.2	–	3,8	15-20	30	6,9	–	
	3	0,5	8.2	–	3,8	5-10	30	8,6	–	
	4	1,0	8.2	–	3,7	5-10	30	5,8	–	
	5	3,0	8.2	–	3,7	5-10	25	7.0	–	
	6	5,0	8.2	–	3,7	5-10	20	8.0	–	

Tab. 27

22°C **CALGON M-570**	0	0.0	7.6	–	3,8	20	300	32,0	–	Points from 1,2 as above
	1	0.1	7.3	–	3,8	< 5	50	8,0	–	
	2	0,3	7.5	–	3,7	< 5	50	8,7	–	
	3	0,5	7.9	–	3,7	< 5	40	9,3	–	
	4	1,0	7.8	–	3,7	< 5	30	9,0	–	
	5	3,0	7,8	–	3,7	< 5	30	9,0	–	
	6	5,0	7,8	–	3,7	< 5	30	10,0	–	

Tab. 28

21°C **CALGON M-580**	0	0,0	7,8	–	3,8	20	300	20,0	–	Points from 1,2 as above
	1	0,1	8,1	–	3,6	< 10	50	13,0	–	
	2	0,3	8,0	–	3,6	< 10	50	11,2	–	
	3	0,5	8,0	–	3,7	< 10	50	10,6	–	
	4	1,0	8,1	–	3,7	< 10	30	10,8	–	
	5	3,0	8,1	–	3,7	< 10	30	10,8	–	
	6	5,0	8,1	–	3,7	< 10	30	15,0	–	

Tab. 29

21°C **CALGON M-550**	0	0,0	7.7	–	3,8	20	300	20,0	–	Points from 1,2 as above
	1	0,1	6,8	–	3,6	20	50	11,0	–	
	2	0,3	6,7	–	3,7	< 10	30	8,2	–	
	3	0,5	6,7	–	3,6	< 10	30	9,0	–	
	4	1,0	6,8	–	3,7	< 5	10	6,8	–	
	5	3,0	6,8	–	3,7	< 5	10	6,8	–	
	6	5,0	6,8	–	3,6	< 5	10	6,8	–	

Tab. 30

1	2	3	4	5	6	7	8	9	10	12
Temp. 21°C **CALGON M - 502**	0	0,0	7,8	–	3,8	20	300	20,0	–	1. Mine waters after 2 hrs of sedimentation 2. C.O.D. determined in filtered off samples.
	1	0,1	6,8	–	3,6	5	15	5,0	–	
	2	0,3	6,7	–	3,6	5	10	5,0	–	
	3	0,5	6,7	–	3,6	5	10	4,8	–	
	4	1,0	6,7	–	3,6	5	10	4,6	–	
	5	3,0	6,8	–	3,6	5	10	4,6	–	
	6	5,0	6,8	–	3,6	5	10	4,4	–	

Tab. 31

23°C **CALGON WT - 2640**	0	0,0	7,8	–	3,8	20	300	20,0	–	Points from 1,2 as above
	1	0,1	7,8	–	3,7	15	150	6,2	–	
	2	0,3	7,8	–	3,7	15	30	5,1	–	
	3	0,5	7,8	–	3,7	15	230	3,2	–	
	4	1,0	7,8	–	3,6	15	25	3,4	–	
	5	3,0	7,8	–	3,6	25	30	4,2	–	
	6	5,0	7,8	–	3,6	25	30	5,0	–	

Tab. 32

23°C **CALGON WT-2570L**	0	0,0	7,8	–	3,8	2,0	300	20,0	–	Points from 1,2 as above
	1	1,0	7,8	–	3,7	opal.	100	10,0	–	
	2	3,0	7,8	–	3,7	opal.	50	8,0	–	
	3	5,0	7,8	–	3,6	opal.	30	8,0	–	
	4	10,0	7,8	–	3,6	opal.	25	8,0	–	
	5	30,0	7,8	–	3,6	10	10	7,5	–	
	6	50,0	7,8	–	3,6	10	10	7,0	–	

Tab. 33

23°C **POLYHALL - 255**	0	0,0	7,8	–	3,8	20	300	20,0	–	Points from 1,2 as above
	1	0,1	7,8	–	3,6	10	50	9,4	–	
	2	0,3	7,8	–	3,7	10	30	7,2	–	
	3	0,5	7,8	–	3,6	10	30	7,8	–	
	4	1,0	7,8	–	3,6	10	30	8,0	–	
	5	3,0	7,8	–	3,7	10	30	8,5	–	
	6	5,0	7,8	–	3,7	10	30	8,8	–	

Tab. 34

1	2	3	4	5	6	7	8	9	10	12
Temp. 23°C **POLYHALL - 297**	0	0.0	7.8	–	3.8	20	300	20.0	–	1. Mine waters after 2 hrs of sedimentation 2. C.O.D. determined in filtered off samples.
	1	0.1	7.8	–	3.8	10	50	7.8	–	
	2	0.3	7.8	–	3.8	10	30	8.0	–	
	3	0.5	7.8	–	3.7	10	30	8.8	–	
	4	1.0	7.8	–	3.7	10	25	9.4	–	
	5	3.0	7.8	–	3.6	10	25	9.5	–	
	6	5.0	7.8	–	3.6	10	25	10.8	–	

Tab. 35

20°C **POLYHALL - 650**	0	0.0	7.8	–	3.7	20	300	20.0	–	Points from 1. 2 as above
	1	0.1	7.8	–	3.7	opal.	150	6.8	–	
	2	0.3	7.8	–	3.7	5	20-30	4.4	–	
	3	0.5	7.8	–	3.7	5	20-30	4.4	–	
	4	1.0	7.8	–	3.7	5	20	5.4	–	
	5	3.0	7.8	–	3.7	10	15	10.0	–	
	6	5.0	7.8	–	3.7	10	15	8.0	–	

Tab. 36

22 °C **POLYHALL - 540**	0	0.0	8.0	–	3.8	20	250	17.0	–	Points from 1. 2 as above
	1	0.1	8.0	–	3.7	opal.	50	9.2	–	
	2	0.3	8.0	–	3.7	20	30	8.0	–	
	3	0.5	8.0	–	3.7	15	30	7.2	–	
	4	1.0	8.0	–	3.7	5	25	7.8	–	
	5	3.0	8.0	–	3.7	10	30	11.6	–	
	6	5.0	8.0	–	3.6	10	25	9.2	–	

Tab. 37

20 °C **CALGON M-502**	0	0.0	8.0		3.8	20	300	15.0	-23.0	Points from 1. 2 as above
	1	10.0	8.0		3.7	< 5	3 - 5	3.4	-22.0	
	2	30.0	8.0		3.7	< 5	3 - 5	3.2	-21.5	
	3	50.0	8.0		3.6	< 5	3 - 5	3.2	-21.0	

Tab. 38

1	2	3	4	5	6	7	8	9	10	12
Temp. 20°C	1	10,0	8,0	–	3,7	<5	3-5	3,6	-21,0	1. Mine waters after 2 hrs of sedimentation.
	2	30,0	8,0	–	3,6	<5	3-5	3,0	-19,0	
CALGON M-503	3	50,0	8,0	–	3,6	<5	3-5	3,0	-17,0	2. C.O.D. determined in filtered off samples.

II SERIES

Tab. 39

Coagulant	Nr	Dose (ppm)	pH before coagul.	pH after coagul.	Basicity (mv)	Color (ppm)	Turbidity (ppm)	C.O.D. (ppm)O_2	Potential ζ mV	Hardnes (° hard.)	Remarks
1	2	3	4	5	6	7	8	9	10	11	12
Temp. 3°C	0	0	7.9	–	3.6	opal.	200	18,5	–	20,0	1. Mine waters after 4 hrs of sedimentation
	1	10	5.0	5.6	0.3	<10	15	6.2	–	20.5	
	2	10	6.0	6.4	1.1	0	10	4,2	–	20,5	2. C.O.D. determined in filtered off samples.
CALGON M-502	3	10	7.9	8,1	3.6	10	10	4,2	–	20,5	
	4	10	9.0	9.1	3.9	11	10	7,4	–	20,5	3. Color designated with SPECOL
	5	10	10.0	9.7	3.3	10	10	4.0	–	15,0	
	6	10	11.0	10.9	4.5	0	0	4.6	–	12.1	

Tab. 40

22°C	0	0	7.8	–	3.7	no mark.	450	25,0	–	13,0	
	1	0,1	7.8	–	3,7	–"–	300	25,0	-23,0	13,0	
	2	0.3	7.8	–	3.7	–"–	450	23,0	-21.0	13,0	
ROKRYSOL WF-1	3	0.5	7.8	–	3.7	–"–	300	23,0	-21,0	12.5	Points from 1 to 3 as above.
	4	1.0	7.8	–	3.5	25	30	18,0	-23,0	12.5	
	5	3,0	7.8	–	3,4	20	20	9,0	-23,0	12,0	
	6	5,0	7.8	–	3,4	15	20	7.0	-23,0	12,0	

Tab. 41

22°C	0	0	7.8	–	3.7	–	450	25,0	–	13,0	
	1	1,0	7.8	–	3.8	–	450	23,0	–	12.5	1. Mine waters after 2 hrs of sedimentation.
	2	3,0	7.8	–	3.7	–	300	22,4	–	12.8	
CALGON M-502	3	5.0	7.8	–	3.7	–	300	20,3	–	12.5	Points from 2 and 3 as above.
	4	10.0	7.8	–	3.6	–	300	16,5	–	12.0	
	5	30,0	7.8	–	3.7	30	30	8.1	–	13.0	
	6	50,0	7.8	–	3.5	18	20	6.3	–	12,0	

Tab. 42

1	2	3	4	5	6	7	8	9	10	11	12
Temp 22°C **ROKRYSOL WF-2**	0	0	7.8	–	3.8	–	>1000	37.0	–	13.0	1. Mine waters after 2 hrs of sedimentation. 2. C.O.D determined in filtered off samples. 3. Color designated with SPECOL
	1	0.1	7.8	–	3.8	–	450	25.1	-33.0	12.5	
	2	0.3	7.8	–	3.7	–	200	12.0	-30.0	12.5	
	3	0.5	7.8	–	3.7	–	300	13.2	-28.0	12.5	
	4	1.0	7.8	–	3.6	28	200	7.2	-24.0	12.5	
	5	3.0	7.8	–	3.5	–	150	7.0	-26.0	12.0	
	6	5.0	7.8	–	3.4	15	150	6.5	-22.0	12.0	

Tab. 43

<1°C **CALGON M-502**	0	0	7.3	–	3.4	–	150	12.5	–	12.8	1. Mine waters after 24 hrs of sedimentation. Points from 2 and 3 as above.
	1	1.0	7.5	–	3.4	22	30	6.4	-47.0	12.5	
	2	3.0	7.6	–	3.4	8	15	5.8	-37.0	12.5	
	3	5.0	7.4	–	3.4	17	5	5.8	-29.0	12.5	
	4	10.0	7.6	–	3.4	6	20	5.8	-20.0	12.5	
	5	30.0	7.5	–	3.4	10	15	5.1	-10.0	12.5	
	6	50.0	7.8	–	3.4	6	30	6.2	+6.0	12.5	

Tab. 44

23°C **POLYHALL 650**	0	0	7.4	–	3.4	–	150	12.5	-	Points from 1 to 3 as above.
	1	1.0	7.4	–	3.4	14	60	5.0	-28.5	
	2	3.0	7.4	–	3.4	9	60	6.6	-27.5	
	3	5.0	7.4	–	3.4	11	60	7.2	-22.0	
	4	10.0	7.4	–	3.4	19	90	7.4	-13.0	
	5	30.0	7.4	–	3.4	14	90	7.6	-7.0	
	6	50.0	7.4	–	3.4	16	90	12.0	+12.0	

VIII SERIES

Tab. 45

Coagulant	Nr	Dose (ppm)	pH before coagul.	pH after coagul.	Basicity F (mv)	Basicity M (mv)	Turbidity (ppm)	Color (ppm) Pt	C.O.D (ppm) O_2	Potential ζ mv	Total hardn. (°hard.)	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13
Temp. 23°C **CALGON 550**	0	0.0					450	–	40.0			Coagulation process not occurred.
	1	0.1					450	–	40.0			
	2	0.3					450	–	40.0			
	3	0.5					450	–	40.0			
	4	1.0					450	–	40.0			
	5	3.0					450	–	40.0			
	6	5.0					450	–	40.0			

Tab. **46**

23°C **CALGON 590**	0	0,0					450	–	40,0			As above
	1	0,1					450	–	40,0			
	2	0,3					450	–	40,0			
	3	0,5					450	–	40,0			
	4	1,0					450	–	40,0			
	5	3,0					450	–	40,0			
	6	5,0					450	–	40,0			

Tab. **47**

23°C **CALGON M-503**	0	0.0					450	–	40.0			As above
	1	0.1					450	–	40.0			
	2	0.3					450	–	40.0			
	3	0.5					450	–	40.0			
	4	1.0					450	–	40.0			
	5	3.0					450	–	40.0			
	6	5.0					450	–	40.0			

Tab. **48**

23°C **CALGON WT-2570 L**	0	0.0					450	–	40.0			As above
	1	0.1					450	–	40.0			
	2	0.3					450	–	40.0			
	3	0.5					450	–	40.0			
	4	1.0					450	–	40.0			
	5	3.0					450	–	40.0			
	6	5.0					450	–	40.0			

Tab. **49**

1	2	3	4	5	6	7	8	9	10	11	12	13
23°C **ROKRYSOL WF-3**	0	0.0					450	–	40.0			Coagulation process not occurred.
	1	0.1					450	–	40.0			
	2	0.3					450	–	40.0			
	3	0.5					450	–	40.0			
	4	1.0					450	–	40.0			
	5	3.0					450	–	40.0			
	6	5.0					450	–	40.0			

Tab. **50**

23°C **ROKRYSOL WF-5**	0	0.0					450	–	40.0			As above.
	1	0,1					450	–	40,0			
	2	0,3					450	–	40,0			
	3	0,5					450	–	40,0			
	4	1,0					450	–	40,0			
	5	3,0					450	–	40,0			
	6	5,0					450	–	40,0			

Tab. **51**

23°C **GIGTAR**	0	0,0					450	–	40,0			As above.
	1	0,1					450	–	40,0			
	2	0,3					450	–	40,0			
	3	0,5					450	–	40,0			
	4	1,0					450	–	40,0			
	5	3,0					450	–	40,0			
	6	5,0					450	–	40,0			

Tab. **52**

23°C **POLYHALL 650**	0	0.0					450	–	40,0			As above.
	1	0,1					450	–	40,0			
	2	0,3					450	–	40,0			
	3	0,5					450	–	40,0			
	4	1,0					450	–	40,0			
	5	3,0					450	–	40,0			
	6	5,0					450	–	40,0			

Tab. **53**

1	2	3	4	5	6	7	8	9	10	11	12	13
23°C **POLYOX**	0	0,0					450	–	40,0			Coagulation commences (flocks appear) by a dose of 3ppm
	1	0,1					450	–	40,0			
	2	0,3					450	–	40,0			
	3	0,5					450	–	40,0			
	4	1,0					450	–	39,0			
	5	3,0					250	–	31,2			
	6	5,0					150	–	20,0			

Tab. 54

23°C Na OH	0	-					450	–	40.0			Similar effects acquired by 10.0 pH reaction as in coagulation process with Polyox dose of 5ppm
	1	-		8.0			450	–	40.0			
	2	-		8.5			450	–	40.0			
	3	-		10.0			150	–	19.4			

Tab. 55

23°C $Ca(OH)_2$	0	0.0					450	-	40.0			As above.
	1	100.0	8.3	8.3	1.0	2.2	80	-	10.0		8.8	
	2	150.0	8.5	8.5	1.5	2.4	20	35.0	6.6		8.5	
	3	200.0	8.7	8.7	1.7	2.5	10	30.0	5.8		8.5	
	4	300.0	9.0	9.0	3.5	4.0	5+10	20.0	5.4		12.5	
	5	400.0	9.7	9.7	8.5	9.1	5	15.0	4.8		25.0	
	6	500.0	10.5	10.5	11.7	12.1	3	15.0	4.4		30.5	

Tab. 56

23°C POLYOX + 100 g/m³ CaO	0	0.0	-				450	-	40.0	-		Process was carried out with participation of calcium in quantity 100 g/m³ of CaO. Determination after 0.5 hr. of sedimentation
	1	0.1	8.3	8.3	1.0	2.2	80	-	9.2	-28.5	8.8	
	2	0.5	8.3	8.3	1.1	2.2	50	-	9.2	-28.5	8.8	
	3	1.0	8.3	8.3	1.0	2.2	50	-	9.0	-28.5	8.8	
	4	2.0	8.3	8.3	1.0	2.2	3+5	30	5.6	-22.0	8.8	
	5	3.0	8.3	8.3	1.0	2.2	5	40	7.6	-23.5	8.8	
	6	5.0	8.3	8.3	1.0	2.2	10	40	7.6	-25.5	8.8	

Tab. 57

1	2	3	4	5	6	7	8	9	10	11	12	13
Temp. 23°C CALGON M-502 +100 g/m³ CaO	0	0.0					450	–	40.0	–		Process was carried out with participation of calcium in quantity 100 g/m³ of CaO. Determination after 0.5 hr. of sedimentation.
	1	0.1	8.3	8.3	1.0	2.2	100	–	10.0	-21.5	8.8	
	2	0.5	8.3	8.3	1.0	2.2	100	–	9.8	-21.5	8.8	
	3	1.0	8.3	8.3	1.0	2.2	30	35	9.0	-22.0	8.8	
	4	2.0	8.3	8.3	1.0	2.2	30	35	9.2	-22.0	8.8	
	5	3.0	8.3	8.3	1.0	2.2	40	–	9.4	-23.0	8.8	
	6	5.0	8.3	8.3	1.0	2.2	60	–	10.4	-23.5	8.8	

Tab. 58

23°C **ROKRYSOL WF - 5** **+100 g/m^3 CaO**	0	0.0					450	–	40.0		8.8	As above.
	1	0.1	8.3	8.3	1.0	2.2	100	–	10.2	-26.5	8.8	
	2	0.5	8.3	8.3	1.0	2.2	80	–	9.4	-26.0	8.8	
	3	1.0	8.3	8.3	1.0	2.2	30	35	9.6	-26.5	8.8	
	4	2.0	8.3	8.3	1.0	2.2	30	35	9.4	-25.5	8.8	
	5	3.0	8.3	8.3	1.0	2.2	25	35	9.4	-25.0	8.8	
	6	5.0	8.3	8.3	1.0	2.2	5	35	8.0	-24.5	8.8	

Tab. 59

Coagulant	Nr.	Dose (ml/dm^3)	Dose (ppm)	Reaction after coagul. pH	Basicity (mv)	Turbidity (ppm)	Color (ppm) Pt	C.O.D. (ppm) O_2	Total Fe (ppm) Fe	Total Fe after filtr. (ppm) Fe	Potential ε mV	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13
Temp. 24°C **ROKRYSOL WF-5** **1 ml = 10 mg** **5 - 6 %**	0	0	0	7.8	3.7	250	Strongly opalized	25.0	0.5	0.3	-26.5	1. Water after 24 hrs of sediment. 2. Rapid mixing 2' 3. Slow mixing 20' 4. Sediment. for 20' 5. Determination of C.O.D. in filtered samples.
	1	1.8	1.0	7.8	3.6	200		17.4	0.15	0.13	-23.0	
	2	5.0	3.0	7.8	3.5	150		13.0	0.13	0.10	-22.0	
	3	10.0	6.0	7.8	3.5	25	–	10.4	0.07	0.07	-20.5	
	4	18.0	10.0	7.8	3.6	10+5	–	8.2	0.05	traces	-18.5	
	5	50.0	30.0	7.8	3.5	50	–	10.8	0.15	0.05	+10.5	
	6	100.0	60.0	7.8	3.5	200	–	13.8	0.25	0.15	+15	

Tab. 60

25°C **CALGON M-502**	0	0	0	7.8	3.7	250	Strongly opalized	25.0	0.5	0.3	-26.5	As above.
	1	1.0	1.0	7.8	3.5	250		22.4	0.15	0.12	-22.0	
	2	3.0	3.0	7.8	3.7	200		18.4	0.15	0.10	-20.0	
	3	5.0	5.0	7.8	3.8	130	–	12.8	0.12	0.10	-19.0	
	4	10.0	10.0	7.8	3.6	60	–	9.6	0.08	0.05	-17.0	
	5	30.0	30.0	7.8	3.7	10	–	3.8	0.05	0.03	-3.0	
	6	50.0	50.0	7.8	3.7	15	–	3.8	0.03	traces	+2.0	

Tab. 61

1	2	3	4	5	6	7	8	9	10	11	12	13
Temp. 24°C **CALCIUM** **D = 100 mg/dm^3** **+CALGON M-550** **1+3** **CALGON M-590** **4+6** 1 ml = 50 mg CaO	0		100+05	7.8	3.8	450	opaliz	45.0	2.5	1.2	–	1. Water without sed. as above. 2. Rapid mixing 2' 3. Slov mixing 20' 4. Sediment. for 20' 5. Determination of C.O.D. in filtered samples.
	1		100+2	9.6	4.9	30	30	10.2	0.08	0.06	-25.5	
	2		100+5	9.6	4.8	5+10	20	8.2	0.03	traces	-23.0	
	3		100+05	9.6	4.9	15	20	8.6	0.08	0.03	-22.5	
	4		100+2	9.6	4.8	50	opaliz	9.6	0.10	0.05	-22.5	
	5		100+5	9.7	4.8	100	opaliz	10.4	0.15	0.08	-22.5	
	6			9.7	4.8	150	opaliz	14.4	0.20	0.10	-32.5	

Tab. 62

24°C CALCIUM $D = 100\ mg/dm^3$ +CALGON WT-2570L 1+3 POLYHALL 650 4+6	0			7,8	3,8	450	opaliz.	45,0	2,5	1,2	–	As above
	1		100+05	9,5	5,1	50	–	11,0	0,08	0,05	-26,5	
	2		100+2	9,5	5,0	30	–	9,8	0,05	0,03	-25,0	
	3		100+5	9,4	5,1	15	20	8,0	0,08	traces	-22,0	
	4		100+05	9,7	4,9	50	–	10,0	0,05	0,05	-22,0	
	5		100+2	9,6	5,0	25	20	9,4	0,05	0,03	-22,0	
	6		100+5	9,6	5,0	25	–	9,6	0,07	0,02	-23,0	

Tab. 63

23°C Coagulation by raised pH with lyes of particular polyelectrolytes	0	0		7,8	3,8	450	opaliz.	45,0	2,5	1,5	–	As above
	1	2,0	Polyox	9,0	5,1	50	–	11,2	0,08	0,05	-41,0	
	2	5,0	WF-5	9,0	5,1	30	–	9,8	0,05	0,03	-25,0	
	3	0,5	M-502	9,0	5,1	50	–	11,2	0,08	0,05	-27,0	
	4	2,0	M-550	9,0	5,2	30	–	10,4	0,03	0,02	-24,0	
	5	5,0	Wt 2570	9,0	4,9	50	–	10,6	0,05	0,05	-33,5	
	6	2,0	M-650	9,0	4,9	50	–	11,0	0,03	traces.	-35,0	

Tab. 64

5°C Coagulation with calcium + POLYOX	0		0	7,8	3,8	450	opaliz.	45,0	2,5	1,5	–	As above
	1		100+01	9,0	2,9	20	50	10,8	traces	traces	-24,0	
	2		100+03	9,0	2,9	50	50	12,2	traces	traces	-23,0	
	3		100+05	9,0	3,1	20	50	9,6	traces	n.occ.	-23,5	
	4		100+1	9,0	3,2	25	45	11,8	traces	n.occ.	-22,5	
	5		100+3	9,0	2,9	15	45	7,6	n.occ.	n.occ.	-22,0	
	6		100+5	9,0	3,1	5+10	45	6,6	n.occ.	n.occ.	-21,5	

Tab. 65

1	2	3	4	5	6	7	8	9	10	11	12	13
Temp. 10°C Coagulation with calcium +POLYOX	0		0	7,8	3,8	450	opaliz	45,0	2,5	1,5	–	Points 1 to 5 as above
	1		100+01	9,0	2,1	15	30	9,0	n.occ.	v.ltl.tr.	-24,0	
	2		100+03	9,0	2,1	30	50	8,6	traces	n.occ.	-22,5	
	3		100+05	9,0	2,1	20	35	9,8	v.ltl.tr	n.occ.	-19,5	
	4		100+1	9,0	2,1	35	50	8,8	traces	n.occ.	-21,5	
	5		100+3	9,0	3,0	5+10	30	8,4	n.occ.	n.occ.	-18,0	
	6		100+5	9,0	2,1	5+10	30	7,0	n.occ.	n.occ.	-19,0	

Tab. 66

16°C Coagulation with calcium +POLYOX	0		0	7.8	3.8	450	not den.	45.0	2.5	1.5	–	As above
	1		100+01	9.0	2.6	25	30	10.6	traces.	traces	-23.5	
	2		100+03	9.0	3.1	30	30	11.2	traces.	traces	-21.5	
	3		100+05	9.0	2.7	25	30	10.0	n.occ.	traces	-19.0	
	4		100+1	9.0	2.7	25	30	11.2	traces	traces	-19.5	
	5		100+3	9.0	2.9	15	25	9.6	traces	n.occ.	-18.5	
	6		100+5	9.0	3.1	15	25	8.8	traces	n.occ.	-17.0	

Tab. 67

16°C Coagulation with calcium +ROKRYSOL WF-5	0		0	7.8	3.8	450	not den.	40.0	2.5	1.5	–	As above
	1		100+01	9.0	2.0	40	50	10.0	0.03	traces.	-28.0	
	2		100+03	9.0	2.2	15	40	9.8	traces	traces	-27.0	
	3		100+05	9.0	2.5	10	40	8.0	traces	traces	-25.5	
	4		100+1	9.0	2.5	40	50	9.0	0.03	traces	-24.0	
	5		100+3	9.0	2.8	50	50	10.0	0.03	traces	-23.5	
	6		100+5	9.0	2.7	10	40	8.4	traces	traces	-24.0	

Tab. 68

5°C Coagulation with calcium +ROKRYSOL WF-5	0		0	7.8	3.8	450	not den.	40	2.5	1.5	–	As above
	1		100+01	9.0	2.6	25	–	10.8	traces	traces	-27.0	
	2		100+03	9.0	2.7	25	40	9.4	n.occ.	n.occ.	-26.0	
	3		100+05	9.0	2.8	15	–	9.0	n.occ.	n.occ.	-24.0	
	4		100+1	9.0	2.8	50	–	10.2	traces	traces	-23.5	
	5		100+3	9.0	3.4	100	–	18.0	1.3	0.03	-23.0	
	6		100+5	9.0	2.5	15	30	10.0	traces	traces	-23.0	

Tab. 69

1	2	3	4	5	6	7	8	9	10	11	12	13
Temp. 10°C Coagulation with calcium +ROKRYSOL WF-5	0		0	7.8	3.8	450	–	40	2.5	1.5	–	Points 1 to 5 as above
	1		100+01	9.0	3.1	30	opaliz.	11.2	traces	traces	-28.0	
	2		100+03	9.0	2.6	25	–	10.6	n.occ.	n.occ.	-26.5	
	3		100+05	9.0	3.1	30	–	10.9	traces	n.occ.	-22.5	
	4		100+1	9.0	3.0	50	–	11.8	traces	traces	-21.5	
	5		100+3	9.0	2.7	30	–	10.4	n.occ.	n.occ.	-21.5	
	6		100+5	9.0	2.7	25	–	10.2	n.occ.	n.occ.	-22.0	

APPENDIX E

ADAMOW MINE WATER

III SERIES

Tab. 70

Coagulant	Nr.	Dose (ppm)	pH before coagul.	pH after coagul.	Basicity (mv)	Color (ppm)	Turbidity (ppm)	C.O.D. (ppm) O_2	Potential ζ mv	Haranes (°hard)	Remarks
1	2	3	4	5	6	7	8	9	10	11	12
Temp. 20°C CALGON M-502	0	0,0	7.7	7.7	4,0	25	300	9.6	-12.5	18.5	1. Mine waters after 2 hrs of sedimentation. 2. Rapid mixing 2' 3. Slow mixing 20' 4. Sedimentation 20' 5. C.O.D. determined in filtered off samples. 6. For the pH correction was used HCL 1+1 and Na OH 2.5 n.
	1	0,1	5.0	5,2	0.2	11	25	2,6	-12,0	18.3	
	2	0,1	6.0	6,1	1.2	25	60	4.6	-12.0	18.4	
	3	0,1	7.7	7.6	3.7	25	80	4,0	-13.5	18,1	
	4	0,1	9,0	8,0	3.3	17	15	2.6	-12,0	15.0	
	5	0.1	10,0	9.4	2.5	16	5	4.0	-19.5	5.0	
	6	0,1	11.0	10,6	4.1	19	5	3,0	-17.0	1.8	

Tab. 71

Temp. 14°C CALGON M-502	0	0,0	7.8	7.8	4.0	25	300	9.6	-12.0	18.5	1. Mine waters after 2 hrs of sedimentation. 2. Rapid mixing 2' 3. Slow mixing 20' 4. Sedimentation 20' 5. C.O.D. determined in filtered off samples. 6. For the pH correction wos used HCl 1+1 and Na OH 2.5 r.
	1	0,1	5.0	4.5	0,1	18	20	4.2	-13.0	18.7	
	2	0,1	6.0	5,8	1.3	20	30	4.8	-13,5	18.7	
	3	0,1	7.8	7.5	4.2	20	25	5.0	-12,0	18.6	
	4	0,1	9.0	8.3	4.5	16	10	4.0	-16.0	18,0	
	5	0,1	10.0	9.0	2,2	12	5	3.4	-17.0	7.0	
	6	0,1	11,0	10.8	4.2	9	3	3.0	-17.0	2.6	

Tab. 72

7°C CALGON M-502	0	0,0	7.5	7.5	4.0	25	300	10,4	-12,5	18.6	Points from 1 to 6 as above.
	1	0,1	5.0	5.3	0.3	16	15	3.4	-15,0	19.0	
	2	0,1	6.0	6,1	1.6	15	10	4.8	-16,5	18.5	
	3	0,1	7.5	7.6	4.1	11	10	5.0	-15,0	18.6	
	4	0,1	9.0	8.5	4.0	14	5	5.0	-12,0	17.0	
	5	0,1	10.0	9.2	2.2	11	3	4.0	-12.5	7.0	
	6	0,1	11.0	10.9	3.8	9	0	3.8	-13,0	3.7	

Tab. 73

1.5°C CALGON M-502	0	0,0	7.7	7.7	4.0	25	300	9,6	-15,0	18.5	Points from 1 to 6 as above.
	1	0,1	5.0	5.3	0.2	12	5	3.2	-16.5	18.4	
	2	0,1	6.0	6,1	1.6	11	10	3,6	-17.0	18.5	
	3	0,1	7.7	7.6	3.8	13	15	3.6	-15.0	18.2	
	4	0.1	9.0	8.1	3.4	14	5	5.2	-16.0	13.1	
	5	0,1	10.0	9.7	2.6	12	3	2.8	-20.0	4.7	
	6	0,1	11.0	10.7	4.4	11	3	2.9	-20.0	2.0	

Tab. 74

1	2	3	4	5	6	7	8	9	10	12
22°C	0	0,0	7,3	7,3	4,2	20	300	13,2	–	
	1	0,10	7,3	8,4	4,1	13	15	5,6	–	
	2	0,30	7,3	8,4	4,1	14	15	5,0	–	
CALGON M-580	3	0,50	7,3	8,4	4,0	13	15	5,0	–	Points from 1 to 5 as above.
	4	1,0	7,3	8,4	4,0	14	15	5,2	–	
	5	3,0	7,3	8,4	4,0	14	15	6,6	–	
	6	5,0	7,3	8,4	3,9	16	15	4,6	–	

Tab. 75

Temp. 22°C	0	0,0	7,2	7,2	4,2	20	300	13,2	-12,5	1. Mine waters after 2 hrs of sedimentation. 2. Rapid mixing 2' 3. Slow mixing 20' 4. Sedimentation 20' 5. C.O.D. determined in filtered off samples. 6. In the test nr 5 and 6 no coagulation occurred.
	1	1,0	7,2	7,2	4,1	19	15	5,2	-12,0	
	2	3,0	7,2	7,2	4,1	16	15	3,6	-10,0	
CALGON M-503	3	5,0	7,2	7,2	4,1	11	15	4,6	-6,5	
	4	10,0	7,2	7,2	4,1	13	15	4,0	-8,5	
	5	30,0	7,2	7,2	not marked			–	+15,5	
	6	50,0	7,2	7,2	not marked			–	+16,5	

Tab. 76

22°C	0	0,0	7,3	7,3	4,2	20	300	13,2	-12,5	
	1	1,0	7,3	7,2	4,1	18	15	5,2	-13,0	
	2	3,0	7,3	7,2	4,1	13	15	6,0	-12,5	
CALGON WT-2570L	3	5,0	7,3	7,2	4,1	15	15	4,2	-13,0	Points from 1 to 5 as above
	4	10,0	7,3	7,2	4,1	15	15	4,8	-12,0	
	5	30,0	7,3	7,2	4,1	16	15	5,2	-12,5	
	6	50,0	7,3	7,2	4,1	16	15	5,2	-12,0	

Tab. 77

22°C	0	0,0	7,3	7,3	4,2	20	300	13,2	-12,5	
	1	0,1	7,3	7,3	4,1	17	15	6,0	-13,0	
	2	0,3	7,3	7,2	4,1	16	15	6,2	-13,0	
POLYHALL 650	3	0,5	7,3	7,2	4,1	18	15	5,6	-13,5	Points from 1 to 5 as above
	4	1,0	7,3	7,3	4,1	17	15	5,8	-16,0	
	5	3,0	7,3	7,2	4,1	15	15	5,6	-16,0	
	6	5,0	7,3	7,3	4,1	16	15	6,0	-15,0	

Tab. 78

1	2	3	4	5	6	7	8	9	10	12
22°C	0	0,0	7.3	7,3	4,2	20	300	13.2	–	Points from 1 to 5 as above
	1	0,1	7.3	7.3	4.1	12	20	4.6	–	
	2	0,3	7.3	7.3	4,1	12	20	4.2	–	
ROKRYSOL WF-1	3	0.5	7.3	7.3	4.1	12	15	5.8	–	
	4	1,0	7.3	7.2	4.0	13	15	5.8	–	
	5	3.0	7.3	7.2	4.0	12	15	6.0	–	
	6	5.0	7.3	7.3	4.0	14	15	6,8	–	

Tab. 79

Temp. 22°C	0	0,0	7.3	7.3	4.2	20	300	13.2	–	1. Mine waters after 2 hrs of sedimentation. 2. Rapid mixing 2' 3. Slow mixing 20' 4. Sedimentation 20' 5. C.O.D determined in filtered off samples.
	1	0,1	7.3	7.2	4.2	17	25	5.6	–	
	2	0,3	7.3	7.2	4.2	14	25	5.0	–	
ROKRYSOL WF-2	3	0,5	7.3	7.2	4.1	14	25	5.2	–	
	4	1.0	7.3	7.2	4.1	16	30	6.0	–	
	5	3.0	7.3	7.3	4.1	14	30	6.8	–	
	6	5,0	7.3	7.3	4.1	14	30	7.0	–	

Tab. 80

23°C	0	0.0	7.3	7.3	4.2	15	300	10.1	–	Points from 1 to 5 as above
	1	0.1	7.3	7.4	4.2	20	90	7.4	–	
	2	0.3	7.3	7.4	4.1	18	90	5.6	–	
POLYOX	3	0.5	7.3	7.3	4.1	14	60	4.8	–	
	4	1.0	7.3	7.2	4.0	13	50	4.8	–	
	5	3.0	7.3	7.3	4.0	15	50	5.4	–	
	6	5.0	7.3	7.4	4.0	17	50	5.2	–	

Tab. 81

22°C	0	0.0	7.3	7.3	4.2	20	300	13.2	–	Points from 1 to 5 as above
	1	0.5	7.3	7.4	4.0	13	10	3.6	–	
	2	1.0	7.3	7.6	4.0	9	10	5.4	–	
CALGON M-502	3	3.0	7.3	7.6	4.0	10	15	4.0	–	
	4	5.0	7.3	7.5	4.0	8	15	4.6	–	
	5	10.0	7.3	7.5	4.0	8	20	4.2	–	
	6	30.0	7.3	7.5	4.0	8	120	4.6	–	

Tab. 82

23°C **CALGON M-502**	0	0.00	7.3	7.3	4.2	20	300	8.0	–	Points from 1 to 5 as above
	1	0.01	7.3	7.3	4.2	20	150	6.0	–	
	2	0.03	7.3	7.3	4.2	20	50	4.8	–	
	3	0.05	7.3	7.3	4.1	17	20	4.8	–	
	4	0.1	7.3	7.3	4.2	15	15	4.8	–	
	5	0.3	7.3	7.3	4.1	12	5	4.8	–	
	6	0.5	7.3	7.3	4.2	12	5	4.0	–	

IV SERIES

Tab. 83

Coagulant	Nr.	Dose (ppm)	pH before coagul.	pH after coagul.	Basicity (mv)	Color (ppm)	Turbidity (ppm)	C.O.D. (ppm) O_2	Potential ζ mv	Hardnes (° hard)	Remarks
1	2	3	4	5	6	7	8	9	10	11	12
Temp. 23°C **CALGON M-502**	0	0.0	7.7	7.7	4.0	15	300	10.0	-17.5	19.5	1. Mine waters after 2 hrs of sedimentation. 2. Rapid mixing 2' 3. Slow mixing 20' 4. Sedimentation 20' 5. C.O.D. determined in filtered off samples. 6. For the pH correction was used HCl 1+1 and NaOH 2.5n
	1	0.3	5.0	5.4	0.5	10	30	6.6	-20.0	18.7	
	2	0.3	6.0	6.2	1.9	9	15	7.2	-24.5	18.7	
	3	0.3	7.7	7.6	3.9	11	20	6.8	-14.5	18.7	
	4	0.3	9.0	8.0	3.3	7	15	5.6	-14.0	14.7	
	5	0.3	10.0	9.6	2.3	8	5	5.4	-23.0	5.0	
	6	0.3	11.0	10.7	3.6	5	3	4.0	-18.0	1.8	

Tab. 84

16°C **CALGON M-502**	0	0.0	7.7	7.7	4.0	20	300	10.0	-17.5	19.5	Points from 1 to 6 as above
	1	0.3	5.0	5.2	0.5	20	20	6.6	-21.5	19.1	
	2	0.3	6.0	6.1	2.1	21	20	7.2	-16.5	18.7	
	3	0.3	7.7	7.6	4.0	15	20	6.8	-19.0	18.8	
	4	0.3	9.0	8.0	3.3	9	20	5.6	-19.0	14.7	
	5	0.3	10.0	9.3	2.0	8	10	5.4	-23.5	5.7	
	6	0.3	11.0	10.7	3.3	0	3	4.0	-21.5	2.5	

Tab. 85

10°C **CALGON M-502**	0	0.0	7.7	7.7	4.0	20	300	8.0	-17.5	19.5	Points from 1 to 6 as above
	1	0.3	5.0	5.2	0.4	14	15	6.8	-18.0	19.4	
	2	0.3	6.0	6.1	2.1	12	20	6.8	-16.5	19.3	
	3	0.3	7.7	7.5	3.9	20	25	6.8	-16.0	18.9	
	4	0.3	9.0	8.0	3.3	12	10	6.2	-19.0	15.2	
	5	0.3	10.0	9.3	2.1	6	10	7.8	-24.0	6.0	
	6	0.3	11.0	10.7	3.5	0	3	6.4	-18.0	2.3	

Tab. 86

1	2	3	4	5	6	7	8	9	10	11	12
2°C **CALGON M-502**	0	0.0	7.5	7.5	4.0	15	300	8.0	-17.5	19.5	Points from 1 to 6 as above
	1	0.3	5.0	5.1	0.5	15	20	7.0	-16.0	19.3	
	2	0.3	6.0	6.1	2.2	13	20	7.2	-18.5	19.3	
	3	0.3	7.5	7.5	3.8	8	20	7.0	-16.5	18.8	
	4	0.3	9.0	7.9	3.1	8	20	6.0	-15.5	15.0	
	5	0.3	10.0	9.0	1.8	7	15	7.0	-21.5	6.0	
	6	0.3	11.0	10.8	3.2	0	3	7.0	-24.0	2.2	

Tab. 87

Temp. 24°C **CALGON M-503**	0	0.0	7.5	7.5	3.9	25	300	8.0	-17.5	1. Mine waters after 2hrs of sedimentation. 2 Rapid mixing 2' 3. Slow mixing 20' 4. Sedimentation 20' 5. C.O.D. determined in filtered off samples. 6. Jn the test nr 6 no coagulation occurred.
	1	1.0	7.6	7.6	3.9	0	15	6.0	-20.5	
	2	3.0	7.5	7.5	3.9	3	15	6.0	-16.5	
	3	5.0	7.5	7.5	3.9	0	15	6.0	-10.5	
	4	10.0	7.6	7.6	3.9	0	10	6.0	+8.5	
	5	30.0	7.5	7.5	3.9	20	15	7.0	+9.5	
	6	50.0	7.6	7.6	3.9	22	300	8.0	+21.5	

Tab. 88

24°C **CALGON WT-2570L**	0	0.0	7.7	7.7	4.1	25	300	11.0	-17.5	Points from 1 to 5 as above
	1	1.0	7.7	7.8	4.0	7	80	7.4	-15.5	
	2	3.0	7.7	7.8	4.0	0	30	7.4	-16.0	
	3	5.0	7.7	7.8	4.0	2	20	7.0	-12.0	
	4	10.0	7.7	7.8	3.9	4	15	8.0	-20.5	
	5	30.0	7.7	7.8	3.8	5	15	7.0	-15.5	
	6	50.0	7.7	7.8	3.8	5	15	7.8	-13.6	

Tab. 89

24°C **CALGON M-580**	0	0.0	7.7	7.7	4.1	25	300	11.0	-18.0	Points from 1 to 5 as above
	1	0.1	7.7	7.6	4.0	3	30	7.0	-18.5	
	2	0.3	7.7	7.7	4.0	3	30	7.6	-20.0	
	3	0.5	7.7	7.7	4.0	2	30	6.6	-17.5	
	4	1.0	7.7	7.7	3.9	3	30	6.6	-20.5	
	5	3.0	7.7	7.7	3.9	0	30	8.0	-17.0	
	6	5.0	7.7	7.7	3.9	0	30	9.6	-17.5	

Tab. 90

1	2	3	4	5	6	7	8	9	10	12
24°C **POLYHALL 650**	0	0.0	7.7	7.7	4.1	25	300	9.8	–	Points from 1 to 5 as above
	1	0.1	7.7	7.5	4.0	2	50	6.8	-17.0	
	2	0.3	7.7	7.6	4.0	2	30	7.0	-25.5	
	3	0.5	7.7	7.6	4.0	3	20	7.2	-10.0	
	4	1.0	7.7	7.6	3.9	3	15	6.6	-12.0	
	5	3.0	7.7	7.6	3.9	3	15	7.4	-15.5	
	6	5.0	7.7	7.6	3.9	3	10	8.0	-12.5	

Tab. 91

Temp. 24°C **POLYOX**	0	0.0	7.7	7.7	4.0	20	300	9.0	-17.5	1. Mine waters after 2hrs of sedimentation. 2. Rapid mixing 2' 3. Slow mixing 20' 4. Sedimentation 20' 5. C.O.D. determinet in filtered off samples.
	1	0.1	7.7	7.7	4.0	16	40	6.6	-19.0	
	2	0.3	7.7	7.8	4.0	5	40	7.0	-18.0	
	3	0.5	7.7	7.8	3.9	5	40	7.0	-16.0	
	4	1.0	7.7	7.8	3.9	2	40	6.6	-19.5	
	5	3.0	7.7	7.9	3.8	0	40	6.8	-21.0	
	6	5.0	7.7	8.0	3.8	5	40	7.4	-19.0	

Tab. 92

24°C **ROKRYSOL WF-3**	0	0.0	7.7	7.7	4.0	20	300	9.0	-17.5	Points from 1 to 5 as above 6. In the test nr 1, 2 and 3 no coagulation occurred.
	1	0.1	7.7	–	not	marked		–	–	
	2	0.3	7.7	–	not	marked		–	–	
	3	0.5	7.7	–	not	marked		–	–	
	4	1.0	7.7	7.7	4.0	10	100	11.6	-19.5	
	5	3.0	7.7	7.7	4.0	20	50	8.4	-21.0	
	6	5.0	7.7	7.7	4.0	15	30	7.4	-13.5	

Tab. 93

24°C **ROKRYSOL WF-3**	0	0.0	7.7	7.7	4.0	20	300	15.0	-17.5	Points from 1 to 5 as above
	1	1.0	7.7	7.7	4.0	20	40	7.4	-11.0	
	2	3.0	7.7	7.8	4.0	15	30	6.6	-11.5	
	3	5.0	7.7	7.7	4.0	8	30	6.6	-17.0	
	4	10.0	7.7	7.7	3.9	8	30	6.8	-14.0	
	5	30.0	7.7	7.7	3.9	10	30	6.4	-21.0	
	6	50.0	7.7	7.7	3.9	10	30	6.8	-19.5	

Tab. 94

1	2	3	4	5	6	7	8	9	10	12
24°C	0	0.0	7.7	7.7	4.0	15	300	7.0	–	Points from 1 to 5 as above 6. Jn the test nr 6 no coagulation occurred.
	1	1.0	7.7	7.7	4.0	0	< 10	6.0	-20.5	
	2	3.0	7.7	7.7	4.0	0	< 10	6.2	-13.0	
CALGON M-502	3	5.0	7.7	7.7	4.0	0	10	6.2	-11.5	
	4	10.0	7.7	7.7	4.0	0	15	6.2	+7.0	
	5	30.0	7.7	7.7	4.0	5	200	8.0	+14.0	
	6	50.0	7.7	7.7	4.0	20	300	9.0	+20.5	

Tab. 95

Temp. 24°C	0	0.00	7.7	7.7	4.0	20	300	11.0	-17.5	Points from 1 to 5 as above 6. Jn the test nr 1 to 2 and 3 no coagulant occurred.
	1	0.01	7.7	–	not marked			–	–	
	2	0.03	7.7	–	not marked			–	–	
CALGON M-502	3	0.05	7.7	–	not marked			–	–	
	4	0.1	7.7	7.7	4.0	10	70	7.4	-17.5	
	5	0.3	7.7	7.7	4.0	7	20	7.0	-18.0	
	6	0.5	7.7	7.7	4.0	5	20	8.4	-18.5	

Tab. 96

24°C	0	0.00	7.7	7.7	4.0	20	300	8.0	-17.5	Points from 1 to 5 as above
	1	0.01	7.7	7.7	4.0	18	200	7.0	-18.5	
	2	0.03	7.7	7.7	4.0	15	70	6.8	-15.5	
CALGON M-502	3	0.05	7.7	7.7	4.0	10	25	7.0	-17.0	
	4	0.1	7.7	7.8	3.9	11	20	7.2	-17.0	
	5	0.3	7.7	7.7	4.0	13	15	6.8	-18.5	
	6	0.5	7.7	7.7	4.0	8	15	7.6	-21.5	

VII SERIES

Tab. 97

Coagulant	Nr	Dose (p.p.m)	pH before coagul.	pH after coagul.	Basicity (mv)	Turbidity (p.p.m)	Color (ppm) Pt	C.O.D. (ppm) O_2	Total Fe ppm	Total filtrated Fe	Potential ζ mV	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13
Temp. 24°C	0	0.0	7.8	7.8	3.6	250	25	23.0	6.2	1.0	-15	1. Mine waters after 2hrs of sediment. 2. Rapid mixing 2' 3. Slow mixing 20' 4. Sedimentation for 20' 5. C.O.D. denoted in filtrated samples.
	1	0.1	7.8	7.8	3.5	70	25	8.0	–	0.1	-15	
	2	0.3	7.8	7.8	3.5	50	25	8.4	–	0.1	-15	
CALGON M-550	3	0.5	7.8	7.8	3.5	30	20	8.6	–	0.1	-16	
	4	1.0	7.8	7.8	3.4	30	20	9.0	–	0.1	-16	
	5	3.0	7.8	7.8	3.4	30	20	9.6	–	0.1	-15	
	6	5.0	7.8	7.8	3.3	30	20	10.0	–	0.1	-15	

Tab. 98

1	2	3	4	5	6	7	8	9	10	11	12	13
24°C **CALGON M-590**	0	0.0	7.8	7.8	3.6	250	25	23.0	6.2	1.0	-15	As above
	1	0.1	7.8	7.8	3.6	50	20	10.0	–	0.12	-16	
	2	0.3	7.8	7.8	3.5	50	20	9.6	–	0.12	-16	
	3	0.5	7.8	7.8	3.5	50	20	9.4	–	0.10	-16,5	
	4	1.0	7.8	7.8	3.4	30	15	9.4	–	0.10	-17	
	5	3.0	7.8	7.8	3.4	30	15	9.2	–	0.09	-18.5	
	6	5.0	7.8	7.8	3.4	30	15	9.0	–	0.09	-20	

Tab. 99

24°C **POLYHALL 650**	0	0.0	7.8	7.8	3.6	250	25	23.0	6.2	1.0	-15	As above
	1	0.1	7.8	7.8	3.5	50	20	10.2	–	0.05	-11.5	
	2	0.3	7.8	7.8	3.5	50	20	10.2	–	0.05	-10	
	3	0.5	7.8	7.8	3.5	40	20	10.2	–	0.05	-11.5	
	4	1.0	7.8	7.8	3.4	30	20	9.4	–	0.05	-12	
	5	3.0	7.8	7.8	3.4	20	15	9.2	–	traces	-14	
	6	5.0	7.8	7.8	3.3	20	15	9.0	–	traces	-16	

Tab. 100

Temp. 22°C **POLYOX**	0	0.0	7.8	7.8	3.6	250	25	25.0	5.7	0.80	-15	Points 1 to 5 as above
	1	0.1	7.8	7.8	3.6	100	25	15.2	1.84	0.90	-16	
	2	0.3	7.8	7.8	3.6	60	25	11.4	1.62	0.76	-16	
	3	0.5	7.8	7.8	3.6	50	25	10.8	1.48	0.44	-15.5	
	4	1.0	7.8	7.8	3.5	50	25	12.6	1.40	0.21	-16	
	5	3.0	7.8	7.8	3.5	50	25	12.8	1.60	0.28	-16	
	6	5.0	7.8	7.8	3.5	50	25	12.8	1.80	0.35	-15	

Tab. 101

22°C **CALGON M-503**	0	0.0	7.8	7.8	3.6	250	25	25.0	6.2	1.0	-15	As above
	1	0.1	7.8	7.8	3.6	80	25	11.0	2.0	0.45	-15	
	2	0.3	7.8	7.8	3.6	50	25	10.2	1.8	0.45	-15.5	
	3	0.5	7.8	7.8	3.6	40	20	9.0	1.76	0.26	-14.5	
	4	1.0	7.8	7.8	3.5	30	20	8.8	1.42	0.20	-13.5	
	5	3.0	7.8	7.8	3.5	30	15	8.4	0.12	0.12	-12.5	
	6	5.0	7.8	7.8	3.5	30	15	8.0	1.06	0.02	-11.0	

Tab. 102

1	2	3	4	5	6	7	8	9	10	11	12	13
22°C	0	0,0	7.8	7.8	3.6	250	25	25.0	6.2	1.0	-15	As above
	1	0,1	7.8	7.8	3,6	250	25	17.0	4,88	1,04	-16	
	2	0,3	7,8	7.8	3,6	200	25	17,2	4.00	0,98	-15,5	
CALGON WT-2570L	3	0.5	7.8	7.8	3,5	100	25	17.0	3,10	0.86	-15,5	
	4	1.0	7.8	7.8	3.5	80	25	11.8	2,68	0,72	-15	
	5	3,0	7.8	7.8	3.5	50	25	10,2	2.00	0,12	-15.5	
	6	5.0	7.8	7.8	3.4	40	20	9.0	1,88	0,06	-13	

Tab. 103

22°C	0	0,0	7.8	7.8	3,6	250	25	25.0	6,2	1,0	-15	As above
	1	0,1	7.8	7,8	3,6	50	25	13,0	1.8	0,52	-15,5	
	2	0,3	7,8	7.8	3,6	30	20	9,2	1,66	0,32	-16	
CALGON M-502	3	0,5	7.8	7,8	3.6	20	20	8.8	1.34	0.11	-16.5	
	4	1,0	7.8	7,8	3.5	20	15	8,0	1,12	0,03	-15	
	5	3,0	7.8	7.8	3.5	20	15	7.4	1.08	0,01	-13	
	6	5.0	7.8	7.8	3.5	20	15	7.0	1.04	traces	-11.5	

Tab. 104

24°C	0	0.0	7.8	7.8	3.6	250	25	25.0	6.2	1.0	-15	Points 1 to 5 as above
	1	2.0	7.8	7.8	3.5	40	20	8.0	0.9	0,08	-16	
	2	6.0	7.8	7.8	3.8	30	20	8.4	0.9	0.08	-16.5	
ROKRYSOL WF-1 6% solution	3	10.0	7.8	7.8	3,5	30	20	9.0	0.9	0.08	-14	
	4	20.0	7.8	7.8	3.5	30	20	9.6	0.9	0.08	-16.5	
	5	60.0	7.8	7.8	3.4	30	20	9.8	0.9	0.07	-16.5	
	6	100.0	7.8	7.8	3.4	30	20	10.0	0.9	0.07	-17.5	

Tab. 105

24°C	0	0.0	7.8	7.8	3.6	250	25	25.0	6.2	1.0	-15	As above.
	1	2.0	7.8	7.8	3.5	50	25	10.0	0.74	0.12	-14.5	
	2	6.0	7.8	7.8	3.5	50	25	10.8	0.74	0.12	-16.5	
ROKRYSOL WF-2 6% solution	3	10.0	7.8	7.8	3.5	50	25	11.4	0.74	0.14	-13	
	4	20.0	7.8	7.8	3.4	50	25	12.0	0.74	0.14	-15.5	
	5	60.0	7.8	7.8	3.4	50	25	12.0	0.74	0.12	-17	
	6	100.0	7.8	7.8	3.3	50	25	12.2	0.74	0.17	-18	

Tab. 106

1	2	3	4	5	6	7	8	9	10	11	12	13
24°C ROKRYSOL WF-3 6% solution	0	0.0	7.8	7.8	3.6	250	25	25.0	6.2	1.0	-15	As above.
	1	2.0	7.8	7.8	3.6	80	25	10.2	1.12	0.40	-15.5	
	2	6.0	7.8	7.8	3.6	50	20	9.8	1.10	0.40	-15	
	3	10.0	7.8	7.8	3.6	40	20	9.8	1.10	0.38	-16.5	
	4	20.0	7.8	7.8	3.5	30	20	10.0	1.05	0.20	-17	
	5	60.0	7.8	7.8	3.5	30	20	10.2	1.00	0.14	-18	
	6	100.0	7.8	7.8	3.5	25	15	10.0	1.00	0.11	-19.5	

Tab. 107

23°C ROKRYSOL WF-5	0	0.0	7.8	7.8	3.6	250	25	23.0	5.7	0.8	-15	As above.
	1	2.0	7.8	7.8	3.5	40	20	8.2	0.48	0.11	-14	
	2	6.0	7.8	7.8	3.5	30	20	8.8	0.33	0.11	-13.5	
	3	10.0	7.8	7.8	3.5	30	20	9.6	0.32	traces	-13	
	4	20.0	7.8	7.8	3.4	30	20	8.6	0.26	traces	-11.5	
	5	60.0	7.8	7.8	3.4	20	15	9.0	0.23	0.0	-10.0	
	6	100.0	7.8	7.8	3.4	20	10	9.0	0.20	0.0	- 8.5	

Tab. 108

Temp. 22°C GIGTAR 7-8% solution	0	0.0	7.8	7.8	3.6	250	25	25.0	5.7	0.80	–	Points 1 to 5 as above. Coagulation within the range of tested samples did not occurred.
	1	2.0	7.8									
	2	6.0	7.8									
	3	10.0	7.8			not	denoted					
	4	20.0	7.8									
	5	60.0	7.8									
	6	100.0	7.8									

Tab. 109

Cagulant 1	Nr 2	Dose (ppm) 3	pH before coagul. 4	pH after coagul. 5	Basicity (mv) 6	Total hardnes o hard. 7	Turbidity (ppm) 8	Color (ppm) Pt 9	C.O.D. (ppm) O_2 10	Fe total (ppm) Fe 11	Fe filtr. total (ppm) Fe 12	Potential ζ mV 13	Remarks 14
Temp. 23°C CALGON M-502	0	0.0	7.8	7.8	3.6	17.0	250	25	23.0	5.7	0.8	-15	1. Mine waters after 2hrs of sediment. 2. Rapid mixing 2' 3. Slow mixing 20' 4. Sedimentation 20' 5. C.O.D. denoted in filtrated of sampl. 6. To pH proofreding wereused: HCL 1+1; NaOH 2.5 m
	1	0.5	5.0	5.3	0.2	17.0	20	20	8.0	0.62	0.26	-14	
	2	0.5	6.0	6.3	0.7	17.0	20	20	8.8	0.62	0.25	-12.5	
	3	0.5	7.8	7.9	3.5	17.0	20	20	8.2	0.68	0.08	-14.5	
	4	0.5	9.0	8.8	4.0	16.0	20	20	8.2	0.69	0.19	-17	
	5	0.5	10.0	9.3	2.5	6.8	20	10	8.4	0.88	0.39	-22.5	
	6	0.5	11.0	10.7	3.5	3.5	10	5	8.0	0.17	traces	-24.5	

Tab. 110

1	2	3	4	5	6	7	8	9	10	11	12	13	14
3°C	0	0.0	7.8	7.8	3.6	17.0	250	25	23.0	5.7	0.8	-15	As above.
	1	0.5	5.0	5.2	0.3	17.1	10	15	7.8	2.08	0.60	-14	
	2	0.5	6.0	6.1	0.5	16.9	10	15	8.0	1.80	0.52	-15	
CALGON M-502	3	0.5	7.8	7.8	3.5	17.0	20	20	8.2	1.20	0.40	-15.5	
	4	0.5	9.0	8.2	4.2	15.8	20	20	8.0	0.92	0.20	-14	
	5	0.5	10.0	9.4	2.8	7.1	10	15	8.2	0.64	traces	-22.5	
	6	0.5	11.0	10.8	3.6	3.6	10	10	7.8	0.52	traces	-25	

Tab. 111

16°C	0	0.0	7.8	7.8	3.6	17.0	250	25	23.0	5.7	0.8	-15	As above
	1	0.5	5.0	5.1	0.2	17.0	10	10	8.2	1.3	0.40	-14	
	2	0.5	6.0	6.3	0.8	17.1	20	15	8.2	1.10	0.32	-13	
CALGON M-502	3	0.5	7.8	8.0	3.6	17.0	20	20	8.6	0.86	0.12	-14	
	4	0.5	9.0	8.3	4.1	16.1	10	15	8.4	0.66	0.05	-17.5	
	5	0.5	10.0	9.3	2.7	6.4	10	15	8.2	0.70	traces	-22.5	
	6	0.5	11.0	10.6	4.0	3.7	10	5	8.0	0.20	traces	-23.5	

X SERIES

Tab. 112

Coagulant	Nr	Dose (ppm)	pH before coagul.	pH after coagul	Basicity (mv)	Turbidity (ppm)	Color (ppm) pt	C.O.D. (ppm) O2	Total Fe (ppm)	Fe filtr. (ppm)	Potential ζ mV	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13
Temp. 20°C	0	0.0	8.0	8.0	4.5	300	20	76.0	8.0	1.50		1. Mine water after 2 hrs of sediment. 2. Rapid mixing 2' 3. Slow mixing 20' 4. Sedimentat. 20' 5. C.O.D. denoted in filtrated samples
	1	0.1	8.0	8.0	4.4	200	20	18.0	1.20	0.40		
	2	0.3	8.0	8.0	4.3	150	20	16.4	1.00	0.30		
CALGON M-502	3	0.5	8.0	8.0	4.2	100	20	16.0	0.90	0.28		
	4	1.0	8.0	8.0	4.2	80	20	14.2	0.70	0.18		
	5	3.0	8.0	8.0	4.1	60	20	12.4	0.52	0.11		
	6	50	8.0	8.0	4.0	50	15	10.0	0.40	0.06		

Tab. 113

20°C	0	0.0	8.0									Points 1 to 4 as above. 5. Not denoted lack of turbidity reduction.
	1	0.1	8.0									
	2	0.3	8.0									
CALGON M-590	3	0.5	8.0									
	4	1.0	8.0									
	5	3.0	8.0									
	6	5.0	8.0									

Tab. 114

1	2	3	4	5	6	7	8	9	10	11	12	13
20°C	0	0.0	8.2									
	1	0.1	8.2									
	2	0.3	8.2									
POLYHALL 650	3	0.5	8.2									As above.
	4	1.0	8.2									
	5	3.0	8.2									
	6	5.0	8.2									

Tab. 115

Temp. 20°C	0	0.0	8.2									
	1	0.1	8.2									
	2	0.3	8.2									Points 1 to 5 as above.
POLYOX	3	0.5	8.2									
	4	1.0	8.2									
	5	3.0	8.2									
	6	5.0	8.2									

Tab. 116

20°C	0	0.0	8.2									
	1	2.0	8.2									
	2	6.0	8.2									
ROKRYSOL WF-5 6-7% solution	3	10.0	8.2									As above
	4	20.0	8.2									
	5	60.0	8.2									
	6	100.0	8.2									

Tab. 117

20°C	0	0.0	8.2									
	1	10.0	8.2									
	2	30.0	8.2									
$Al_2/SO_4/_3 \cdot .18 H_2O$	3	50.0	8.2									As above
	4	100.0	8.2									
	5	150.0	8.2									
	6	200.0	8.2									

1	2	3	4	5	6	7	8	9	10	11	12	13
$Fe_2/SO_4/_3 \cdot . n\,H_2O$	0	0,0	8,0	8,0	4,5	300	20	78,0	8,0	1,50	-16,0	1. Mine waters after 2hrs of sedim. 2. Rapid mixing 2' 3. Slow mixing 20' 4. Sedimentat. 20' 5. C.O.D. denoted in filtrated samples.
	1	5,0	8,0	7,8	4,0	250	20	20,0	1,40	1,00	-19,5	
	2	10,0	8,0	7,7	3,6	200	20	13,2	1,20	0,80	-17,0	
	3	20,0	8,0	7,7	3,4	100	20	11,3	1,00	0,60	-18,0	
	4	30,0	8,0	7,5	3,0	50	20	6,0	0,30	0,18	-15,0	
	5	40,0	8,0	7,2	2,7	30	15	5,0	0,18	0,11	-14,5	
	6	50,0	8,0	7,0	2,5	10	15	4,0	0,09	0,07	-13,5	

APPENDIX F

KONIN-PATNOW MINE WATER

V SERIES

Tab. 119

Coagulant	Nr.	Dose (ppm)	pH before coagul.	pH after coagul.	Basicity (mv)	Color (ppm)	Turbidity (ppm)	C.O.D. (ppm) O_2	Potential ζ mv	Hardnes (°hard.)	Remarks
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Temp. 23°C	0	0.0	7.7	7.7	6.7	25	200	9.2	-23.0	18.8	1. Mine water after 2hrs of sedimentation. 2. Rapid mixing 2' 3. Slow mixing 20' 4. Sedimentation 20' 5. C.O.D. determined in filtered off samples. 6. Calcium employed in a from of whitewash 1 ml = 20 mg
	1	50.0	7.7	8.2	4.7	10	200	6.0	-16.0	13.3	
	2	100.0	7.7	8.8	2.8	8	100	6.2	-15.5	7.6	
CALCJUM	3	150.0	7.7	10.0	2.1	6	50	6.0	-15.0	5.8	
	4	200.0	7.7	11.0	1.5	5	30	6.0	-14.0	5.9	
	5	250.0	7.7	11.7	2.0	3	15	5.0	-9.0	6.1	
	6	300.0	7.7	12.0	3.5	3	5	4.8	-3.0	8.6	

Tab. 120

22°C	0	0.0	7.7	7.7	6.7	25	200	9.0	-23.0	18.8	Points from 1 to 5 as above 6. For the pH correction was used HCl 1+1 and NaOH 2.5 n.
	1	0.5	5.0	5.2	1.5	2	15	7.8	-19.5	17.8	
	2	0.5	6.0	6.2	4.5	3	15	6.8	-22.0	17.6	
CALGON M-502	3	0.5	7.7	7.8	6.2	4	15	6.6	-20.5	17.4	
	4	0.5	9.0	8.0	5.1	2	15	6.4	-19.0	10.6	
	5	0.5	10.0	9.6	5.4	3	20	7.0	-23.0	6.0	
	6	0.5	11.0	10.9	8.1	2	20	7.6	-27.5	5.8	

Tab. 121

Temp. 2°C	0	0.0	7.7	7.7	6.7	25	200	9.0	-23.0	18.7	Points from 1 to 6 as above.
	1	0.5	5.0	5.2	1.6	11	40	7.0	-13.5	18.7	
	2	0.5	6.0	6.1	4.1	8	30	6.8	-18.5	18.5	
CALGON M-502	3.	0.5	7.7	7.8	5.7	9	30	6.8	-14.5	18.2	
	4	0.5	9.0	8.1	4.3	7	20	6.8	-11.5	15.2	
	5	0.5	10.0	9.3	4.7	5	15	7.2	-17.5	5.3	
	6	0.5	11.0	10.6	6.3	3	10	7.0	-16.0	2.0	

Tab. 122

8°C	0	0.0	7.7	7.7	6.7	25	200	9.0	-23.0	18.7	Points from 1 to 6 as above.
	1	0.5	5.0	5.1	1.3	10	40	7.2	-14.0	18.6	
	2	0.5	6.0	6.1	3.8	9	30	7.0	-20.0	18.7	
CALGON M-502	3	0.5	7.7	7.6	4.6	10	30	7.0	-18.0	17.8	
	4	0.5	9.0	8.0	4.2	6	15	6.8	-16.0	14.8	
	5	0.5	10.0	9.5	3.9	4	10	6.9	-21.5	5.1	
	6	0.5	11.0	10.8	5.4	4	10	7.0	-27.5	3.2	

Tab. 123

1	2	3	4	5	6	7	8	9	10	11	12
15°C CALGON M-502	0	0.0	7.7	7.7	6.7	25	200	9,0	-23.0	18.7	Points from 1 to 6 as above.
	1	0,5	5.0	5,1	2.0	11	40	7.2	-17.0	18.6	
	2	0,5	6,0	6.2	4.0	10	30	6,8	-17.0	18.7	
	3	0,5	7.7	7.7	4.8	8	20	6.8	-16,5	18.5	
	4	0,5	9,0	8,1	4.2	6	15	6.6	-18,0	15.0	
	5	0,5	10.0	9,6	4,3	7	10	7.2	-21.0	5,4	
	6	0,5	11.0	10,8	5.2	4	10	7.2	-23.5	3,3	

Tab. 124

1	2	3	4	5	6	7	8	9	10	12
POLYHALL 650	0	0.0	7.7	7.7	6.7	25	250	8.6	-23.0	Points from 1 to 6 as above
	1	0.1	7.7	7.7	6.5	12	120	6.6	-21.5	
	2	0.3	7.7	7.7	6.4	5	70	6.2	-18.5	
	3	0.5	7.7	7.7	6.4	3	60	6.4	-17.0	
	4	1.0	7.7	7.8	6.3	3	50	7.6	-22.0	
	5	3.0	7.7	7.8	6.3	4	20	8.8	-22.0	
	6	5.0	7.7	7.8	6.2	6	10	9.4	-14.0	

Tab. 125

CALGON WT 2570L	0	0.0	7.7	7.7	6.7	25	250	9.0	-23.0	1. Mine waters after 2 hrs of sedimentation. 2. Rapid mixing 2' 3. Slow mixing 20' 4. Sedimentation 20' 5. C.O.D. determined in filtered off samples.
	1	1.0	7.7	7.8	6.5	25	140	7.4	-16.0	
	2	3.0	7.7	7.8	6.4	20	90	5.8	-15.0	
	3	5.0	7.7	7.8	6.4	16	60	6.0	-16.0	
	4	10.0	7.7	7.8	6.3	10	40	5.6	-14.5	
	5	30.0	7.7	7.8	6.3	4	30	6.2	-15.5	
	6	50.0	7.7	7.8	6.3	2	25	6.6	-15.5	

Tab. 126

CALGON M-580	0	0.0	7.7	7.7	6.7	25	250	9.0	-23.0	Points from 1 to 5 as above.
	1	0.1	7.7	7.9	6.4	25	100	7.4	-15.5	
	2	0.3	7.7	7.9	6.4	25	90	6.8	-18.0	
	3	0.5	7.7	7.9	6.4	17	90	7.0	-16.0	
	4	1.0	7.7	7.9	6.3	15	80	7.6	-16.0	
	5	3.0	7.7	7.9	6.2	17	80	8.4	-21.0	
	6	5.0	7.7	7.9	6.2	17	80	9.4	-17.0	

Tab. 127

1	2	3	4	5	6	7	8	9	10	12
Temp. 22°C	0	0.0	7.7	7.7	6.7	25	250	9.0	-23.0	Points from 1 to 5 as above.
	1	1.0	7.7	7.8	6.4	15	60	6.4	-17.0	
	2	3.0	7.7	7.8	6.4	9	50	5.8	-20.5	
CALGON M-503	3	5.0	7.7	7.8	6.4	5	40	5.2	-15.0	
	4	10.0	7.7	7.8	6.4	5	40	5.4	-11.5	
	5	30.0	7.7	–	not marked			–	–	
	6	50.0	7.7	–	not marked			–	–	

Tab. 128

22°C	0	0.0	7.7	7.7	6.7	25	250	9.2	-23.0	Points from 1 to 5 as above
	1	0.1	7.7	7.9	6.4	16	70	6.4	-18.0	
POLYOX	2	0.3	7.7	7.9	6.4	17	70	5.8	-18.0	
	3	0.5	7.7	7.9	6.4	15	50	6.0	-16.5	
	4	1.0	7.7	7.9	6.4	12	50	5.2	-18.0	
	5	3.0	7.7	7.9	6.3	10	50	6.0	-16.0	
	6	5.0	7.7	7.9	6.2	8	60	6.2	-18.0	

Tab. 129

Temp. 23°C	0	0.0	7.7	7.7	6.7	25	200	9.2	-23.0	1. Mine waters after 2hrs of sedimentation. 2 Rapid mixing 2' 3. Slow mixing 20' 4. Sedimentation 20' 5. C.O.D. determined in filtered off samples.
	1	1.0	7.7	7.6	6.5	18	100	6.8	-16.0	
	2	3.0	7.7	7.6	6.5	12	70	6.4	-17.5	
ROKRYSOL WF-1	3	5.0	7.7	7.6	6.4	10	50	6.6	-16.5	
	4	10.0	7.7	7.6	6.3	8	30	6.4	-20.0	
	5	30.0	7.7	7.7	6.3	8	30	5.8	-18.0	
	6	50.0	7.7	7.7	6.3	7	30	6.2	–	

Tab 130

22°C	0	0.0	7.8	7.8	6.7	25	200	9.0	-23.0	Points from 1 to 5 as above
	1	1.0	7.8	7.7	6.5	15	130	7.8	-15.0	
	2	3.0	7.8	7.7	6.4	13	60	8.8	-18.0	
ROKRYSOL WF-3	3	5.0	7.8	7.8	6.3	15	50	7.4	-15.5	
	4	10.0	7.8	7.8	6.2	13	50	6.0	-14.0	
	5	30.0	7.8	7.8	6.1	13	30	6.0	-18.5	
	6	50.0	7.8	7.8	6.0	7	30	6.2	-15.5	

Tab 131

1	2	3	4	5	6	7	8	9	10	12
22°C **GIGTAR**	0	0.0	7.8	7.8	6.7	25	200	9.0	-23.0	Points from 1 to 5 as above
	1	1.0	7.8	7.7	6.5	13	120	6.8	-13.5	
	2	3.0	7.8	7.8	6.4	11	70	6.4	-16.5	
	3	5.0	7.8	7.8	6.3	10	60	6.4	-16.0	
	4	10.0	7.8	7.7	6.2	9	50	6.8	-15.0	
	5	30.0	7.8	7.8	6.1	11	60	7.2	-18.0	
	6	50.0	7.8	7.8	6.0	10	70	7.0	–	

Tab. 132

23°C **CALGON M-502**	0	0.0	7.8	7.8	6.7	25	200	9.2	-23.0	Points from 1 to 5 as above
	1	0.1	7.8	7.8	6.5	15	30	5.2	-16.0	
	2	0.3	7.8	7.8	6.4	10	30	5.4	-15.0	
	3	0.5	7.8	7.9	6.3	8	30	5.8	-14.0	
	4	1.0	7.8	7.9	6.3	8	30	6.0	-16.5	
	5	3.0	7.8	7.9	6.2	7	30	6.2	-15.0	
	6	5.0	7.8	7.9	6.2	10	30	6.0	-14.0	

Tab. 133

Temp. 23°C **CALGON M-502**	0	0.0	7.8	7.8	6.7	25	200	9.2	-23.0	1. Mine waters after 2 hrs of sedimentation. 2. Rapid mixing 2' 3. Slow mixing 20' 4. Sedimentation 20' 5. C.O.D. determined in filtered off samples.
	1	0.05	7.8	7.9	6.7	11	180	9.0	-15.0	
	2	0.1	7.8	7.9	6.6	11	160	8.4	-14.5	
	3	0.2	7.8	7.9	6.4	11	100	7.0	-14.5	
	4	0.3	7.8	7.9	6.3	10	70	6.4	-15.5	
	5	0.4	7.8	7.9	6.3	9	60	6.0	-16.0	
	6	0.5	7.8	7.9	6.2	8	30	5.6	-12.5	

VI SERIES

Tab. 134

Coagulant	Nr.	Dose (ppm)	pH before coagul.	pH after coagul.	Basicity (mv)	Color (ppm)	Turbidity (ppm)	C.O.D. (ppm) O2	Potential ζ mv	Hardnes (°hard)	Remarks
1	2	3	4	5	6	7	8	9	10	11	12
Temp. 23°C **CALGON M-502**	0	0.0	7.7	7.7	4.3	20	200	13.5	-18.5	16.8	Points from 1 to 5 as above 6. For the pH correction was used HCl 1+1 and NaOH 2,5n
	1	0.3	5.0	5.4	0.4	10	10	7.0	-16.5	16.8	
	2	0.3	6.0	6.2	1.7	10	10	7.2	-14.5	16.8	
	3	0.3	7.7	7.7	4.2	10	10	7.8	-15.5	16.7	
	4	0.3	9.0	8.1	3.7	10	10	8.4	-16.5	13.5	
	5	0.3	10.0	9.8	3.1	10	10	8.0	-22.5	4.1	
	6	0.3	11.0	10.8	4.3	5	5	8.4	-25.5	2.7	

Tab, 137

1	2	3	4	5	6	7	8	9	10	11	12
3°C	0	0.0	7.7	7.7	4.3	20	200	13.5	-18.5	16.8	Points from 1 to 6 as above
	1	0.3	5.0	5.1	0.3	15	10	6.8	-19.0	16.8	
	2	0.3	6.0	6.2	1.8	15	10	6.8	-16.5	16.7	
CALGON M-502	3	0.3	7.7	7.6	4.2	10	10	7.0	-13.0	16.6	
	4	0.3	9.0	8.2	3.5	10	10	7.2	-13.5	12.8	
	5	0.3	10.0	9.7	3.0	10	5	7.6	-21.0	4.3	
	6	0.3	11.0	10.8	4.2	10	5	8.0	-25.0	2.6	

Tab. 136

15°C	0	0.0	7.7	7.7	4.3	20	200	13.2	-18.5	16.8	Points from 1 to 6 as above
	1	0.3	5.0	5.2	0.5	15	10	7.0	-18.0	16.7	
	2	0.3	6.0	6.2	1.9	10	10	7.2	-16.0	16.8	
CALGON M-502	3	0.3	7.7	7.7	4.1	10	10	7.2	-16.0	16.7	
	4	0.3	9.0	8.0	3.8	10	10	7.6	-16.5	13.2	
	5	0.3	10.0	9.6	3.2	10	10	8.0	-21.5	4.3	
	6	0.3	11.0	10.7	4.3	5	5	8.2	-27.0	2.8	

Tab. 137

1	2	3	4	5	6	7	8	9	10	12
Temp. 22°C	0	0.0	7.6	7.6	4.3	20	200	14.5	-18.5	1. Mine water after 2 hrs of sedimentation. 2. Rapid mixing 2' 3. Slow mixing 20' 4. Sedimentation 20' 5. C.O.D. determined in filtered of samples.
	1	0.1	7.6	7.6	4.2	20	90	9.0	-22.5	
	2	0.3	7.6	7.6	4.1	20	20	8.0	-21.5	
CALGON M-503	3	0.5	7.6	7.6	4.1	15	15	7.2	-18.0	
	4	1.0	7.6	7.6	4.0	10	10	7.0	-17.5	
	5	3.0	7.6	7.6	4.0	10	10	6.8	-16.0	
	6	5.0	7.6	7.6	3.9	5	10	6.8	-13.0	

Tab. 138

22°C	0	0.0	7.7	7.7	4.3	20	200	15.0	-18.5	Points from 1 to 5 as above.
	1	0.1	7.7	7.7	4.3	20	200	9.2	-26.0	
	2	0.3	7.7	7.7	4.3	20	150	8.6	-23.0	
CALGON WT-2570 L	3	0.5	7.7	7.7	4.2	15	100	7.5	-26.0	
	4	1.0	7.7	7.8	4.2	15	50	7.4	-20.5	
	5	3.0	7.7	7.8	4.1	10	30	7.2	-19.0	
	6	5.0	7.7	7.8	4.1	10	20	7.0	-19.0	

Tab. 139

1	2	3	4	5	6	7	8	9	10	12
22°C	0	0.0	7.7	7.7	4.3	20	200	15.0	-18.5	Points from 1 to 5 as above.
	1	0.1	7.7	7.7	4.2	20	80	8.8	-18.0	
	2	0.3	7.7	7.7	4.2	20	50	8.8	-20.0	
POLYHALL - 650	3	0.5	7.7	7.7	4.1	20	40	8.8	-18.0	
	4	1.0	7.7	7.7	4.0	15	30	8.8	-19.0	
	5	3.0	7.7	7.7	3.9	15	25	8.6	-20.0	
	6	5.0	7.7	7.7	3.8	15	20	8.4	-22.0	

Tab. 140

22°C	0	0.0	7.7	7.7	4.3	20	200	15.0	-18.5	Points from 1 to 5 as above.
	1	0.12	7.7	7.7	4.3	20	30	8.8	-16.0	
	2	0.36	7.7	7.7	4.3	20	25	8.4	-14.0	
ROKRYSOL WF-3	3	0.6	7.7	7.7	4.2	20	25	8.0	-17.0	
	4	1.2	7.7	7.7	4.2	20	20	10.0	-15.5	
	5	3.6	7.7	7.7	4.2	15	20	10.0	-15.5	
	6	6.0	7.7	7.7	4.2	15	20	10.2	-13.0	

Tab. 141

Temp. 22°C	0	0.0	7.7	7.7	4.3	20	200	12.0	-18.5	1. Mine waters after 2hrs of sedimentation. 2. Rapid mixing 2' 3. Slow mixing 20' 4. Sedimentation 20' 5. C.O.D. determined in filtered off samples.
	1	0.1	7.7	7.7	4.2	20	25	9.0	-18.0	
	2	0.3	7.7	7.7	4.2	20	10	8.0	-16.0	
CALGON M-502	3	0.5	7.7	7.8	4.1	15	5	8.0	-14.5	
	4	1.0	7.7	7.8	4.0	15	5	8.0	-12.5	
	5	3.0	7.7	7.8	4.0	10	5	7.4	-15.5	
	6	5.0	7.7	7.9	4.0	10	10	7.0	-10.5	

Tab. 142

22°C	0	0.0	7.8	7.8	4.3	20	200	12.0	-18.5	Points from 1 to 5 as above.
	1	0.1	7.8	7.8	4.3	20	30	8.6	-17.5	
	2	0.3	7.8	7.8	4.2	15	30	8.4	-16.0	
POLYOX	3	0.5	7.8	7.8	4.2	15	30	8.4	-18.0	
	4	1.0	7.8	7.8	4.1	15	30	8.4	-15.0	
	5	3.0	7.8	7.8	4.1	15	30	8.6	-17.5	
	6	5.0	7.8	7.9	4.0	15	30	9.0	-15.0	

Tab. 143

1	2	3	4	5	6	7	8	9	10	12
22°C	0	0,0	7.7	7.7	4.3	20	200	13,5	-18.5	Points from 1 to 5 as above.
	1	0,1	7.7	7.7	4.2	20	25	8.6	-16,0	
	2	0,3	7.7	7.7	4.2	20	30	8.8	-16,0	
CALGON M-580	3	0,5	7.7	7.7	4,1	20	50	9,0	-16,0	
	4	1,0	7.7	7.8	4,1	20	70	9,6	-16,0	
	5	3,0	7.7	7.8	4,0	20	100	9,8	-16,0	
	6	5,0	7.7	7.8	4.0	20	150	10,0	-16,0	

IX SERIES

Tab. 144

Coagulant	Nr	Dose (ppm)	pH before coagul.	pH after coagul.	Basicity (mv)	Turbidity (ppm)	Color (ppm) Pt	C.O.D. (ppm) O2	Total iron (ppm)	Total iron after filtr. (ppm) Fe	Remarks
1	2	3	4	5	6	7	8	9	10	11	12
Temp. 23°C	0	0,0	7.8	7.8	6.5	250	25	16.0	0.60	0,15	1. Mine waters after 2 hr of sediment. 2. Rapid mixing 2' 3. Slow mixing 20' 4. Sedimentation 20' 5. C.O.D. denoted in filtrated samples.
	1	0,1	7.8	7.8	6.5	60	25	8.2	0.30	0.10	
	2	0,3	7.8	7.8	6.5	50	25	7.8	0.20	0,06	
CALGON M-503	3	0,5	7.8	7.8	6.4	40	20	7.2	0,16	0.06	
	4	1.0	7.8	7.8	6.3	30	20	7.0	0.16	traces	
	5	3,0	7.8	7.8	6.1	30	20	7.0	0,12	traces	
	6	5.0	7.8	7.8	6.2	30	15	7.2	0,12	traces	

Tab. 145

23°C	0	0,0	7.8	7.8	6.5	250	25	16,0	0,60	0,15	Points 1 to 5 as above
	1	0,1	7.8	7.8	6,5	30	25	6.6	0.28	0,09	
	2	0.3	7.8	7.8	6.4	20	20	5,6	0.12	traces	
CALGON M-502	3	0,5	7.8	7.8	6,3	15	20	5,6	0.12	traces	
	4	1.0	7.8	7.8	6.3	15	15	5.6	0.12	traces	
	5	3,0	7.8	7.8	6,2	15	15	6.0	0.11	0.0	
	6	5.0	7.8	7.8	6.1	15	15	6.4	0.11	0,0	

Tab. 146

1	2	3	4	5	6	7	8	9	10	11	12
23°C	0	0.0	7.8	7.8	6.5	250	25	16.0	0.60	0.15	1. Mine water after 2 hr of sedimentation. 2. Rapid mixing 2' 3. Slow mixing 20' 4. Sedimentation 20' 5. C.O.D. denoted in filtrated samples
	1	0.1	7.8	7.8	6.5	60	25	8.6	0.24	0.12	
	2	0.3	7.8	7.8	6.4	60	25	8.4	0.18	0.08	
CALGON M-550	3	0.5	7.8	7.8	6.4	50	20	8.6	0.14	0.06	
	4	1.0	7.8	7.8	6.3	40	20	8.2	0.14	0.06	
	5	3.0	7.8	7.8	6.3	40	20	8.0	0.14	0.01	
	6	5.0	7.8	7.8	6.2	40	20	7.6	0.14	0.01	

Tab. 147

1	2	3	4	5	6	7	8	9	10	11	12
23°C CALGON M-590	0	0.0	7.8	7.8	6.5	250	25	16.0	0.60	0.15	As above
	1	0.1	7.8	7.8	6.5	120	25	7.8	0.20	0.09	
	2	0.3	7.8	7.8	6.4	100	25	7.2	0.18	0.08	
	3	0.5	7.8	7.8	6.4	90	25	7.4	0.18	0.08	
	4	1.0	7.8	7.8	6.3	80	25	8.0	0.16	0.08	
	5	3.0	7.8	7.8	6.3	80	20	8.4	0.14	0.06	
	6	5.0	7.8	7.8	6.3	80	20	8.6	0.16	0.06	

Tab. 148

23°C POLYHALL 650	0	0.0	7.8	7.8	6.5	250	25	16.0	0.60	0.15	As above
	1	0.1	7.8	7.8	6.4	120	25	7.0	0.24	0.08	
	2	0.3	7.8	7.8	6.4	100	25	6.8	0.20	0.06	
	3	0.5	7.8	7.8	6.3	60	20	6.4	0.16	0.01	
	4	1.0	7.8	7.8	6.3	50	20	7.0	0.14	traces	
	5	3.0	7.8	7.8	6.3	40	20	7.6	0.11	traces	
	6	5.0	7.8	7.8	6.2	40	10	8.2	0.11	0.01	

Tab. 149

22.5°C POLYOX	0	0.0	7.8	7.8	6.5	250	25	12.0	0.60	0.15	As above
	1	0.1	7.8	7.7	6.5	40	25	8.0	0.13	0.0	
	2	0.3	7.8	7.8	6.4	40	20	6.6	0.12	0.0	
	3	0.5	7.8	7.8	6.4	30	20	7.6	0.12	0.0	
	4	1.0	7.8	7.8	6.4	30	20	6.0	0.11	0.0	
	5	3.0	7.8	7.8	6.4	30	15	6.4	0.11	0.0	
	6	5.0	7.8	7.8	6.3	30	15	7.8	0.11	0.0	

Tab. 150

1	2	3	4	5	6	7	8	9	10	11	12
Temp. 22.5°C ROKRYSOL WF-1 6% solution	0	0.0	7.8	7.8	6.5	250	25	12.0	0.60	0.15	Points 1 to 5 as above
	1	2.0	7.8	7.8	6.5	150	25	8.2	0.30	0.11	
	2	6.0	7.8	7.8	6.4	100	25	7.8	0.22	0.06	
	3	10.0	7.8	7.8	6.4	80	25	7.8	0.14	0.06	
	4	20.0	7.8	7.8	6.4	50	20	7.4	0.12	0.04	
	5	60.0	7.8	7.8	6.3	40	20	6.4	0.12	0.02	
	6	100.0	7.8	7.8	6.3	40	20	6.6	0.12	0.01	

Tab. 151

1	2	3	4	5	6	7	8	9	10	11	12
23°C ROKRYSOL WF-2 6% solution	0	0,0	7,8	7,8	6,5	250	25	16,0	0,60	0,15	As above
	1	2,0	7,8	7,8	6,4	200	25	8,4	0,26	0,10	
	2	6,0	7,8	7,8	6,5	150	25	8,2	0,20	0,10	
	3	10,0	7,8	7,8	6,3	100	25	7,6	0,16	0,10	
	4	20,0	7,8	7,8	6,3	70	20	7,2	0,11	0,04	
	5	60,0	7,8	7,8	6,3	50	20	6,8	0,14	0,01	
	6	100,0	7,8	7,8	6,2	50	20	7,0	0,11	0,01	

Tab. 152

23°C ROKRYSOL WF-3 6% solution	0	0,0	7,8	7,8	6,5	250	25	16,0	0,60	0,15	As above
	1	2,0	7,8	7,8	6,4	80	25	8,0	0,18	0,08	
	2	6,0	7,8	7,7	6,4	60	20	7,6	0,16	0,04	
	3	10,0	7,8	7,7	6,3	50	20	7,4	0,11	0,02	
	4	20,0	7,8	7,8	6,3	40	15	7,0	0,10	0,01	
	5	60,0	7,8	7,8	6,2	30	15	6,6	0,08	0,01	
	6	100,0	7,8	7,7	6,2	30	15	5,8	0,04	traces	

Tab. 153

23°C ROKRYSOL WF-5 6% solution	0	0,0	7,8	7,8	6,5	250	25	16,0	0,60	0,15	As above
	1	2,0	7,8	7,7	6,4	40	20	6,2	0,13	0,02	
	2	6,0	7,8	7,5	6,4	20	20	5,8	0,13	0,01	
	3	10,0	7,8	7,6	6,3	15	15	6,0	0,12	0,01	
	4	20,0	7,8	7,6	6,2	20	15	4,8	0,12	0,01	
	5	60,0	7,8	7,7	6,2	20	10	5,2	0,08	traces	
	6	100,0	7,8	7,6	6,2	30	10	4,6	0,08	traces	

Tab. 154

1	2	3	4	5	6	7	8	9	10	11	12
GIGTAR 7-8% solution	0	0,0	7,8	7,8	6,5	250	25	16,0	0,60	0,15	Points 1 to 5 as above
	1	2,0	7,8	7,8	6,4	150	25	8,8	0,16	0,11	
	2	6,0	7,8	7,8	6,4	100	25	8,4	0,18	0,08	
	3	10,0	7,8	7,8	6,3	80	25	8,0	0,16	0,08	
	4	20,0	7,8	7,8	6,2	80	25	8,2	0,10	0,04	
	5	60,0	7,8	7,8	6,2	100	25	8,2	0,10	0,04	
	6	100,0	7,8	7,8	6,1	100	25	8,4	0,10	0,04	